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# CARNEGIE INSTITUTION OF WASHINGTON

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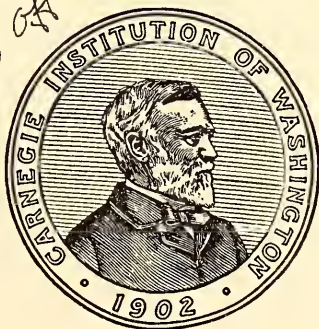
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JULY 1, 1936—JUNE 30, 1937

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WITH ADMINISTRATIVE REPORTS THROUGH DECEMBER 10, 1937

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## PRESIDENT AND TRUSTEES

### PRESIDENT

JOHN C. MERRIAM

### BOARD OF TRUSTEES

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**Finance Committee:** FREDERIC C. WALCOTT, *Chairman*

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ALFRED L. LOOMIS	ELIHU ROOT JR.

**Auditing Committee:** FREDERIC A. DELANO, *Chairman*

HOMER L. FERGUSON	WILLIAM BENSON STOREY
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## FORMER PRESIDENTS AND TRUSTEES

### PRESIDENTS

DANIEL COIT GILMAN, 1902-04

ROBERT SIMPSON WOODWARD, 1904-20

### TRUSTEES

ALEXANDER AGASSIZ	1904-05	WAYNE MACVEAGH	1902-07
GEORGE J. BALDWIN	1925-27	ANDREW J. MELLON	1924-37
JOHN S. BILLINGS	1902-13	DARIUS O. MILLS	1902-09
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SIMON FLEXNER	1910-14	HENRY S. PRITCHETT	1906-36
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LYMAN J. GAGE	1902-12	JULIUS ROSENWALD	1929-31
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JOHN HAY	1902-05	WILLIAM H. TAFT	1906-15
MYRON T. HERRICK	1915-29	WILLIAM S. THAYER	1929-32
ABRAM S. HEWITT	1902-03	CHARLES D. WALCOTT	1902-27
HENRY L. HIGGINSON	1902-19	HENRY P. WALCOTT	1910-24
ETHAN A. HITCHCOCK	1902-09	WILLIAM H. WELCH	1906-34
HENRY HITCHCOCK	1902-02	ANDREW D. WHITE	1902-16
WILLIAM WIRT HOWE	1903-09	EDWARD D. WHITE	1902-03
CHARLES L. HUTCHINSON	1902-04	HENRY WHITE	1913-27
SAMUEL P. LANGLEY	1904-06	GEORGE W. WICKERSHAM	1909-36
WILLIAM LINDSAY	1902-09	ROBERT S. WOODWARD	1905-24
HENRY CABOT LODGE	1914-24	CARROLL D. WRIGHT	1902-08
SETH LOW	1902-16		

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

# STAFF OF INVESTIGATORS FOR THE YEAR 1937

## PHYSICAL SCIENCES

Advisory Committee on Physical Sciences: F. E. WRIGHT, *Chairman*

W. S. ADAMS  
J. A. FLEMING

H. A. SPOEHR  
J. STEBBINS  
E. B. WILSON

### *Geophysical Laboratory*

Organized in 1906, opened in 1907; Arthur L. Day, Director 1907-1936.

§L. H. ADAMS, *Acting Director*  
\*N. L. BOWEN  
JOHN S. BURLEW  
†C. N. FENNER  
MICHAEL FLEISCHER  
R. E. GIBSON  
R. W. GORANSON  
J. W. GREIG  
J. H. HIBBEN  
EARL INGERSON  
F. C. KRACEK

C. J. KSANDA  
H. E. MERWIN  
G. W. MOREY  
CHARLES S. PIGGOT  
EUGENE POSNJAK  
H. S. ROBERTS  
J. F. SCHAIRER  
E. S. SHEPHERD  
GEORGE TUNELL  
F. E. WRIGHT  
E. G. ZIES

### *Mount Wilson Observatory*

Organized in 1904; George E. Hale, Director 1904-1923, Honorary Director 1923-1936.

WALTER S. ADAMS, *Director*  
F. H. SEARES, *Assistant Director*  
ALFRED H. JOY, *Secretary*  
A. S. KING, *Supt. Physical Laboratory*  
J. A. ANDERSON  
WALTER BAADE  
HAROLD D. BABCOCK  
THEODORE DUNHAM JR.  
‡FERDINAND ELLERMAN  
EDWIN P. HUBBLE

MILTON L. HUMASON  
PAUL W. MERRILL  
SETH B. NICHOLSON  
FRANCIS G. PEASE  
EDISON PETTIT  
R. S. RICHARDSON  
R. F. SANFORD  
SINCLAIR SMITH  
GUSTAF STRÖMBERG  
A. VAN MAANEN  
OLIN C. WILSON

### *Department of Terrestrial Magnetism*

Organized in 1904; L. A. Bauer, Director 1904-1929.

J. A. FLEMING, *Director*  
O. H. GISH, *Assistant Director*  
L. V. BERKNER  
F. T. DAVIES  
\*\*C. R. DUVAL  
††C. C. ENNIS  
S. E. FORBUSH  
JOHN W. GREEN  
L. R. HAFSTAD  
N. P. HEYDENBERG  
E. A. JOHNSON

H. F. JOHNSTON  
P. G. LEDIG  
A. G. MCNISH  
WILFRED C. PARKINSON  
W. J. ROONEY  
W. E. SCOTT  
K. L. SHERMAN  
OSCAR W. TORRESON  
M. A. TUVE  
G. R. WAIT  
W. F. WALLIS  
H. W. WELLS

§ Appointed Director January 1, 1938.

\* Resigned October 1, 1937.

† Retired August 1, 1937.

‡ Retired June 1, 1937.

\*\* Retired February 1, 1937.

†† Retired July 1, 1937.

## *Committee on Meridian Astrometry*

BENJAMIN BOSS, *Chairman*  
HARRY RAYMOND

RALPH E. WILSON

## **DIVISION OF PLANT BIOLOGY: H. A. SPOEHR, *Chairman***

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923; reorganized in 1928 as Division of Plant Biology, including Ecology.

JENS C. CLAUSEN  
FREDERIC E. CLEMENTS  
WALDO S. GLOCK  
WM. M. HIESEY  
DAVID D. KECK  
FRANCES L. LONG

T. D. MALLERY  
EMMETT MARTIN  
H. W. MILNER  
FORREST SHREVE  
JAMES H. C. SMITH  
H. H. STRAIN

## **DIVISION OF ANIMAL BIOLOGY: GEORGE L. STREETER, *Chairman***

An administrative grouping made effective in 1935, including activities of the following Departments:

### *Department of Embryology*

Organized in 1914; Franklin P. Mall, Director 1914-1917.

GEORGE L. STREETER, *Director*  
CARL G. HARTMAN  
CHESTER H. HEUSER

MARGARET R. LEWIS  
WARREN H. LEWIS  
CHARLES W. METZ

### *Department of Genetics*

Station for Experimental Evolution, opened in 1904, was combined with Eugenics Record Office in 1921 to form Department of Genetics. Charles B. Davenport, Director 1904-1934.

A. F. BLAKESLEE, *Director*  
M. DEMEREC, *Assistant Director*  
H. H. LAUGHLIN, *Assistant Director*  
A. G. AVERY  
R. W. BATES  
A. DOROTHY BERGNER

B. P. KAUFMANN  
E. C. MACDOWELL  
JAMES S. POTTER  
OSCAR RIDDLE  
SOPHIA SATINA  
MORRIS STEGGERDA

### *Nutrition Laboratory*

Organized in 1907, opened in 1908.

\*FRANCIS G. BENEDICT, *Director*  
T. M. CARPENTER

V. COROPATCHINSKY  
ROBERT C. LEE

### *Tortugas Laboratory*

Established in 1904. Alfred G. Mayor, Director 1904-1922; W. H. Longley, Executive Officer 1924-1937. Open for marine biological studies during summer months.

D. H. TENNENT, *Executive Officer*

\* Retired November 1, 1937.

## DIVISION OF HISTORICAL RESEARCH: A. V. KIDDER, *Chairman*

Department of Historical Research was organized in 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905-1928. In 1930 this Department was incorporated as the Section of United States History in a new Division of Historical Research.

### *Section of Aboriginal American History*

SYLVANUS G. MORLEY  
EARL H. MORRIS  
H. E. D. POLLOCK  
O. G. RICKETSON JR.  
H. B. ROBERTS  
KARL RUPPERT  
A. LEDYARD SMITH  
GUSTAV STRÓMSVIK  
J. ERIC THOMPSON

### *Section of Post-Columbian American History*

RALPH L. ROYS  
FRANCE V. SCHOLES  
LEO F. STOCK

### *Section of the History of Science*

GEORGE SARTON  
ALEXANDER POGO  
MARY WELBORN

## RESEARCH ASSOCIATES

ERNST ANTEVS, Climatology  
C. B. BRIDGES, Biology  
BARBARA S. BURKS, Genetics  
ALFONSO CASO, Archaeology  
VERNE E. CHATELAIN, History  
PAUL S. CONGER, Biology

A. E. DOUGLASS, Climatology  
F. A. PERRET, Geophysics  
ARTHUR J. ROY, Astronomy  
JACK SCHULTZ, Biology  
HARRY O. WOOD, Seismology

### Research Associates Engaged in Post-retirement Studies

EDMUND C. BURNETT, History  
CHARLES B. DAVENPORT, Biology  
ARTHUR L. DAY, Geophysics  
GEORGE E. HALE, Astronomy

D. T. MACDOUGAL, Plant Physiology  
W. J. PETERS, Terrestrial Magnetism  
GODFREY SYKES, Physiography

### Research Associates Connected with Other Institutions

SOPHIE D. ABERLE (U. S. Office of Indian Affairs), Anthropology  
ERNEST ANDERSON (University of Arizona), Plant Biology  
M. J. ANDRADE (University of Chicago), Linguistics  
E. B. BABCOCK (University of California), Genetics  
I. W. BAILEY (Bussey Institute), Plant Biology  
J. BARTELS (Forstliche Hochschule, Eberswalde), Terrestrial Magnetism  
V. BJERKNES (University of Oslo, Norway), Meteorology  
G. BREIT (University of Wisconsin), Physics  
J. P. BUWALDA (California Institute of Technology), Geology and Palæontology  
W. E. CASTLE (University of California), Biology  
RALPH W. CHANEY (University of California), Palæobotany  
S. CHAPMAN (Imperial College, London), Terrestrial Magnetism  
A. H. COMPTON (University of Chicago), Physics  
L. S. CRESSMAN (University of Oregon), Archaeology  
H. DE TERRA (Academy of Natural Sciences of Philadelphia), Archaeology and Palæontology  
L. R. DICE (University of Michigan), Biology  
TH. DOBZHANSKY (California Institute of Technology), Genetics  
G. GAMOW (George Washington University), Terrestrial Magnetism  
W. A. HEIDEL (Wesleyan University), History of Science

NORMAN E. A. HINDS (University of California), Geology  
 EDGAR B. HOWARD (University of Pennsylvania), Archæology and Palæontology  
 J. H. JEANS (Royal Society of London), Astronomy  
 THOMAS H. JOHNSON (Bartol Research Foundation), Physics  
 REMINGTON KELLOGG (United States National Museum), Palæontology  
 S. A. KORFF (Bartol Research Foundation), Physics  
 A. E. KENNELLY (Harvard University), Terrestrial Magnetism  
 E. A. LOWE (The Institute for Advanced Study), Palæography  
 C. L. LUNDELL (University of Michigan), Botany  
 EDWIN D. MCKEE (U. S. National Park Service), Geology and Palæontology  
 R. A. MILLIKAN (California Institute of Technology), Physics  
 S. A. MITCHELL (University of Virginia), Astronomy  
 T. H. MORGAN (California Institute of Technology), Biology  
 ROBERT REDFIELD (University of Chicago), Anthropology  
 E. G. RITZMAN (New Hampshire Agricultural Experiment Station), Nutrition  
 HENRY A. RUGER (Columbia University), Psychology  
 G. OSCAR RUSSELL (Ohio State University), Physiology  
 HENRY N. RUSSELL (Princeton University), Astronomy  
 A. H. SCHULTZ (Johns Hopkins University), Anthropology  
 H. C. SHERMAN (Columbia University), Nutrition  
 JOEL STEBBINS (University of Wisconsin), Astronomy  
 CHESTER STOCK (California Institute of Technology), Palæontology  
 H. U. SVERDRUP (Scripps Institution of Oceanography), Terrestrial Magnetism  
 H. B. VICKERY (Connecticut Agricultural Experiment Station), Physiological Chemistry  
 G. H. R. VON KOENIGSWALD (Bandong, Java), Palæontology  
 IRA L. WIGGINS (Stanford University), Plant Biology  
 BAILEY WILLIS (Stanford University), Seismology  
 E. B. WILSON (Harvard University), Climatology

## OFFICES OF ADMINISTRATION

JOHN C. MERRIAM, *President*

### *Office of the President*

JOHN C. MERRIAM, *President*  
 WALTER M. GILBERT, *Administrative Secretary*  
 SAMUEL CALLAWAY, *President's Secretary*

### *Office of Publications*

FRANK F. BUNKER, *Editor*  
 IRVING M. GREY, *Secretary*

### *Advisory Committee on Public Progress Reports*

F. E. WRIGHT, <i>Chairman</i>	H. A. SPOEHR
A. V. KIDDER	G. L. STREETER

### *Office of the Bursar*

EDMUND A. VARELA, *Bursar*  
 EARLE B. BIESECKER, *Assistant Bursar*



## ORGANIZATION, PLAN, AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use and a sum of five million dollars has been paid by the Carnegie Corporation of New York as an increase to the Endowment Fund of the Institution, payments having been completed in 1931. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

The Institution is essentially an operating organization. It attempts to advance fundamental research in fields not normally covered by the activities of other agencies, and to concentrate its attention upon specific problems, with the idea of shifting attack from time to time to meet the more pressing needs of research as they develop with increase of knowledge. Some of these problems require the collaboration of several investigators, special equipment, and continuous effort. Many close relations exist among activities of the Institution, and a divisional type of organization, representing investigations in plant biology, in animal biology, and in historical research, has been effected in order to make possible a larger degree of unity and closer cooperation. An advisory committee representing the interests of the Institution in the physical sciences facilitates research in that field. Conference groups on various subjects have played a part in bringing new vision and new methods to bear upon many problems. Constant efforts are made to facilitate interpretation and application of results of research activities of the Institution, and an Office of Publications provides means for appropriate publication, both in the form of technical monographs and as news bulletins.

## ARTICLES OF INCORPORATION

PUBLIC No. 260.—An Act To incorporate the Carnegie Institution of Washington

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees herein-after appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, *Samuel P. Langley*, William Lindsay, Seth Low, Wayne MacVeagh,



## ARTICLES OF INCORPORATION

Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Hitchcock*, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said

## ARTICLES OF INCORPORATION

trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904

# BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, December 13, 1912, and December 10, 1937

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## ARTICLE I

### THE TRUSTEES

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

## ARTICLE II

### MEETINGS

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

## ARTICLE III

### OFFICERS OF THE BOARD

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

## BY-LAWS OF THE INSTITUTION

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

### ARTICLE IV

#### EXECUTIVE ADMINISTRATION

##### *The President*

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

### ARTICLE V

#### COMMITTEES

1. There shall be the following standing Committees, *viz.* an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio*



## BY-LAWS OF THE INSTITUTION

and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of five members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

## BY-LAWS OF THE INSTITUTION

### ARTICLE VI

#### FINANCIAL ADMINISTRATION

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

### ARTICLE VII

#### AMENDMENT OF BY-LAWS

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

ABSTRACT OF MINUTES OF THE THIRTY-EIGHTH  
MEETING OF THE BOARD OF TRUSTEES

The meeting was held in Washington in the Board Room of the Administration Building on Friday, December 10, 1937. It was called to order by the Vice-Chairman, Mr. Forbes.

Upon roll call, the following Trustees responded: Thomas Barbour, James F. Bell, Robert Woods Bliss, Frederic A. Delano, W. Cameron Forbes, Walter S. Gifford, Frank B. Jewett, Charles A. Lindbergh, Roswell Miller, Henry S. Morgan, Stewart Paton, John J. Pershing, William Benson Storey, Richard P. Strong, Charles P. Taft, Frederic C. Walcott, and Lewis H. Weed.

The minutes of the thirty-seventh meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Chairmen of Divisions, Directors of Departments, and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1938 were authorized:

Pension Fund .....	\$60,000
Administration .....	64,550
Publications (including Office of Publications) .....	97,220
Departments and Divisions of Research.....	1,084,078
Minor Grants .....	115,500
General Contingent Fund.....	110,000
Special Emergency Reserve Fund.....	130,000
	<hr/>
	\$1,661,348

Balloting for new Trustees to fill two vacancies, caused by the deaths of Mr. Mellon and Mr. Root, resulted in election of Elihu Root Jr., of New York, and Henry R. Shepley, of Boston, Massachusetts.

Mr. Forbes was elected to fill the unexpired term of Mr. Root as Chairman of the Board, and Mr. Gifford was elected to fill the unexpired term of Mr. Forbes as Vice-Chairman of the Board.

Mr. Bliss was elected to fill the unexpired term of Mr. Forbes as a member of the Executive Committee, Mr. Forbes having become *ex officio* member of this Committee by reason of his election as Chairman of the Board.

Upon recommendation of the Executive Committee, an amendment of the By-Laws of the Institution was adopted authorizing increase in membership of the Finance Committee from three to five members. Section 5, Article V, of the By-Laws therefore now reads as follows:

“The Finance Committee shall consist of five members to be elected by the Board of Trustees for a term of three years.”

Henry S. Morgan and Elihu Root Jr. were thereupon elected to serve as additional members of the Finance Committee, in accordance with specifications of the amended By-Law, for a term corresponding in length to the unexpired term of other members of this Committee ending in December 1939.

The Chairman presented the following resolution, which was unanimously adopted:

WHEREAS, The Honorable Elihu Root at the time of his death in March, 1937, had served thirty-four years as Trustee of the Carnegie Institution of Washington, and

WHEREAS, As member and Chairman of the Executive Committee, and as Chairman of the Board of Trustees, he has given much of his time and thought to the affairs of the Institution, and

WHEREAS, An important part of the success of the Carnegie Institution of Washington has been due to the wisdom, foresight, devotion, and enthusiastic support of Mr. Root; now therefore be it

*Resolved*, That the auditorium now under construction in the addition to the Administration Building of the Institution in Washington be hereafter known as the "Elihu Root Hall"; and be it further

*Resolved*, That there should be placed in the hall a suitable memorial which shall serve as an expression of appreciation by the Institution of the debt of gratitude it owes to its great leader.

The meeting adjourned at 12:35 p.m.



# REPORT OF THE EXECUTIVE COMMITTEE

For the Year Ending October 31, 1937

*To the Trustees of the Carnegie Institution of Washington:*

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1937.

During this year the Executive Committee held five meetings, printed reports of which have been mailed to each Trustee.

Upon adjournment of the meeting of the Board of Trustees of December 11, 1936, the members of the Executive Committee met and organized by the election of Mr. Forbes as Chairman for 1937.

A full statement of the work of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. A detailed estimate of expenditures for the succeeding year is also contained in the report of the President, and has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted therewith. Close attention has been given both by the Executive Committee and by the Finance Committee to the question of availability of funds for Institution activities in 1938, and budget recommendations are based upon judgment of these Committees with respect to financial policy for protection both of capital and of income, and concerning the problem of investment of funds.

The Board of Trustees, at its meeting of December 11, 1936, appointed Arthur Young and Company to audit the accounts of the Institution for the fiscal year ending October 31, 1937. The report of the Auditor, including a balance sheet showing assets and liabilities of the Institution on October 31, 1937, will be submitted as a part of the report of the Executive Committee.

In addition to the report of the Auditor there will also be submitted a financial statement for the fiscal year ending October 31, 1937, showing funds available for expenditure and amounts allotted by the Executive Committee, and a customary statement of receipts and disbursements since the organization of the Institution on January 28, 1902. These statements together with the tables in the Auditor's report comprise a full statement of the finances of the Institution.

Under authority of the Executive Committee during the past year an architect has been appointed to prepare plans and specifications for the proposed addition to the Administration Building, which will be used primarily for advancing the public relations program of the Institution.

Plans have been approved for this building, a contract has been let, and construction of the building is under way, in expectation that it will be ready for occupancy in the fall of 1938.

Written notice has been mailed to members of the Board of a proposal approved by the Executive Committee for amendment of the By-Laws of the Institution whereby the Finance Committee shall consist of five, instead of three, members.

Two vacancies exist in membership of the Board of Trustees, caused by the death of Elihu Root on February 7, 1937, and the death of Andrew W. Mellon on August 26, 1937. Nominations to fill vacancies have been requested, received, and distributed in accordance with provisions of the By-Laws, and such nominations will be submitted to the Board at its annual meeting on December 10, 1937.

A vacancy exists in the Chairmanship of the Board of Trustees due to the death of Mr. Root. For the same reason there is also a vacancy in membership of the Executive Committee.

W. CAMERON FORBES, *Chairman*  
 FREDERIC A. DELANO  
 WALTER S. GIFFORD  
 JOHN C. MERRIAM  
 STEWART PATON  
 FREDERIC C. WALCOTT  
 LEWIS H. WEED

November 19, 1937

*Financial Statement for Fiscal Year Ending October 31, 1937*

	Balances unallotted Oct. 31, 1936	Trustees' appropri- ation Dec. 13, 1936	Revert- ments and transfers Nov. 1, 1936, to Oct. 31, 1937	Total available 1937	Executive Committee allotments 1937	Transfers by Execu- tive Com- mittee	Unallotted balances Oct. 31, 1937
Large Grants:							
Animal Biology:							
Administrative Expenses.....		\$1,700		\$1,700	\$1,700		
Embryology.....		75,688	2,450	78,138	78,138		
Genetics.....		133,195	5,785.21	138,980.21	138,980.21		
Nutrition Laboratory.....		42,120		42,120	42,120		
Tortugas Laboratory.....		14,000	1,000	15,000	15,000		
Geophysical Laboratory.....		151,172	19,600	170,772	170,772		
Historical Research.....		151,030	7,700	158,730	158,730		
Mount Wilson Observatory.....		215,845	1,236.67	217,081.67	217,081.67		
Plant Biology.....		99,020	15,050	114,070	114,070		
Terrestrial Magnetism.....		184,247	9,180	193,427	193,427		
Minor Grants.....	5,161.87	104,750	17,725.19	127,637.06	122,340		5,297.06
Publications.....	34,136.95	97,520	13,266.12	144,923.07	89,182.10		55,740.97
Administration.....		64,950	9,871.28	74,821.28	74,821.28		
Pension Fund.....		60,000		60,000	60,000		
General Contingent Fund.....	21,588.91	100,000	30,007.29	151,596.20	38,004.35	67,563.16	46,028.69
Special Emergency Reserve Fund.....		125,000		125,000	125,000		
	60,887.73	1,620,237	132,871.76	1,813,996.49	1,639,366.61	67,563.16	107,066.72

*Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1937*

RECEIPTS		DISBURSEMENTS		
<i>Interest from Securities and Bank Balances</i> .....	\$42,328,112.81	<i>Investments (*)</i> .....		\$63,557,504.44
<i>Colburn Fund</i> .....	52,015.74	<i>Pension Fund</i> .....		865,404.65
<i>Sales of Publications</i> .....	330,684.98	<i>Insurance Fund</i> .....		114,324.68
<i>Revertments</i> .....	774,982.23	<i>General Contingent Fund</i> .....		165,663.48
<i>Pension Fund</i> .....	81,078.10	<i>Special Emergency Reserve Fund</i> .....		121,291.14
<i>Insurance Fund</i> .....	12,194.63	<i>Special Reserve Fund for Administration Bldg. Additions</i> .....		17,120.02
<i>Special Reserve Fund for Administration Building Additions (Rentals)</i> .....	15,477.96	<i>Grants</i> .....		
<i>Redemption and Sale of Bonds</i> .....	52,819,553.23	<i>Large</i> .....	\$29,024,250.25	33,979,901.46
<i>Carnegie Corporation of N. Y.</i> .....	7,495,881.24	<i>Minor</i> .....	4,955,651.21	
<i>Miscellaneous</i> .....	6,684.96	<i>Publications</i> .....		2,458,540.74
	103,916,665.88	<i>National Research Council</i> .....		150,000.00
		<i>Administration</i> .....		2,033,930.53
		<i>Cash in Banks</i> .....		103,463,681.14
				452,984.74
				103,916,665.88

(\*) Including Administration Building, \$309,915.69, and Collection Charges.



## REPORT OF AUDITORS

TO THE BOARD OF TRUSTEES  
*Carnegie Institution of Washington*  
*Washington, D. C.*

We have made an examination of the books and accounts of CARNEGIE INSTITUTION OF WASHINGTON for the year ended October 31, 1937.

Income from investments and other sources has been duly accounted for and all disbursements were evidenced by paid voucher checks and/or properly approved invoices. The cash and securities were either verified by inspection or by certificates received from depositaries and custodians. As in the past years, the detailed accounts of the Departments of Research in the field have been audited by the Bursar of the Institution and we are of the opinion, as a result of reviewing the internal audit methods in force, that such internal audit is satisfactorily conducted.

The securities are stated at cost or value at date acquired, this being the established custom of the Institution. Real estate and equipment are stated at original cost and books on hand for sale at their sales prices.

We inspected certified copies of the minutes of the meetings of the Board of Trustees and Executive Committee as authority for the appropriations and allotments made during the year.

In our opinion, on the basis of valuations above stated, the accompanying Balance Sheet, statement of Receipts and Disbursements and detailed Schedule of Securities properly present the financial position of the CARNEGIE INSTITUTION OF WASHINGTON at October 31, 1937, and the transactions for the year ended that date.

ARTHUR YOUNG & COMPANY  
*Accountants and Auditors*

*New York, N. Y., November 26, 1937*

Balance Sheet, October 31, 1937

ASSETS		LIABILITIES		
<i>Investments</i>		<i>Endowment and Other Funds</i>		
Securities.....		<i>Capital Funds</i>		
Cash.....	\$35,697,772.86	Endowment.....	\$30,303,411.31	
Awaiting investment.....	47,695.95	Colburn Fund.....	113,130.50	
Reserved for current needs.....	19,298.77	Reserve Fund.....	3,207,129.16	
		Harriman Fund (\$183,-		
		671.75 included in Prop-		
		erty Fund below).....	303,451.70	\$33,927,122.67
		<i>Special Funds</i>		
		Insurance Fund.....		651,497.01
		Pension Fund.....		343,434.18
		Special Emergency Re-		
		serve Fund.....		422,986.09
<i>Property Account</i>		Special Reserve Fund for		
Real Estate and Equipment at original		Administration Building		
cost.....	414,158.29	Additions.....		139,156.62
Office of Administration.....	3,677,912.16	Current Funds, Invested.		160,000.00
Departments of Research.....				35,644,196.57
		Increase from redemption		
		and sale of securities		
		(awaiting yearly appor-		
		tionment).....		120,571.01
				\$35,764,767.58
<i>General Fund</i>		<i>Property Fund</i>		
Cash.....		Income Invested.....		3,908,398.70
Income account.....	\$385,990.02	Harriman Property (Gift) ..		183,671.75
Petty cash and stamps.....	500.00			
	386,490.02	<i>General Fund</i>		
		Current Obligations		
		Large Grants.....	282,761.94	
		Minor Grants.....	50,891.33	
		Publications.....	129,930.43	
		Administration.....	20,626.58	
		General Contingent Fund..	68,570.21	
Income uncollected for the year 1937..	79,731.60			
		Unappropriated Fund....	552,780.49	
			73,441.13	
		Less Current Funds,	626,221.62	
		Invested (see above) ..		466,221.62
Books on hand at sale price.....	269,622.05			
Outstanding accounts on sales of				
publications.....	568.16	Value of Publications and		
Paper in stock for future publications..	5,489.77	Invoices.....	270,190.21	
		Publication Paper Stock....	5,489.77	741,901.60
				40,598,739.63



RECEIPTS		DISBURSEMENTS	
<i>Interest and Dividends from Securities</i> .....	\$1,731,828.40	<i>Investments</i>	\$3,636,872.86
<i>Sales of Publications</i>		<i>Securities</i> .....	7,214.18
Index Medicus.....	\$47.60	<i>Accrued interest purchased</i> .....	
Year Book.....	88.10	<i>Pension Fund</i> .....	70,667.68
Miscellaneous Books.....	4,528.49	<i>Insurance Fund</i> .....	6,323.36
<i>Reversions</i>		<i>General Contingent Fund</i> .....	36,651.23
Large Grants		<i>Special Emergency Reserve Fund</i> .....	43.59
Departments.....	2,459.12	<i>Special Reserve Fund for Administration Building Additions</i> .....	5,389.35
Contributions	2,400.00	<i>Grants</i>	
National Research Council.....		Large.....	1,173,366.99
California Institute of Technology.....	12,599.88	Minor.....	142,172.20
International Cancer Research Foundation.....	2,750.00	<i>Publication</i>	
Geological Society of America.....	2,950.00	General Publication.....	61,874.04
Rockefeller Foundation.....	3,100.00	Catalogues, Advertising, etc.....	1,156.91
		Shipping Expenses.....	7,095.36
		Office of Publications.....	26,202.28
Minor Grants.....	26,259.00	<i>Administration</i>	
Publication.....	3,105.14	Trustees.....	1,750.33
Administration.....	4,032.13	Executive Committee.....	2,288.77
Unappropriated Fund.....	964.60	Salaries.....	48,559.65
General Contingent Fund.....	251.19	Surety, postage, tel. and tel.....	2,275.09
	180.76	Printing, paper.....	1,222.95
<i>Pension Fund</i> .....		Office expenses.....	9,792.08
<i>Insurance Fund</i> .....		Equipment.....	270.73
<i>Special Reserve Fund for Administration Building Additions (Rentals)</i> .....		Building, maintenance.....	4,510.80
		Lectures and Exhibits.....	1,899.06
<i>Redemption and Sale of Securities</i> .....			72,569.46
<i>Carnegie Corporation of N. Y.</i> .....		<i>Cash in Banks</i>	5,247,599.49
		Uninvested Principal	
		Awaiting investment.....	47,695.95
		Reserved for current needs.....	19,298.77
<i>Balance in Banks, October 31, 1936</i> .....		<i>Income Account</i> .....	66,994.72
			385,990.02
			452,984.74
			5,700,584.23

### Schedule of Securities

Aggregate— Par or Nominal Value	Description	Registered		Maturity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Railways</i>					
\$500,000	A. T. & S. Fe. 1st & ref. 4½s. ....			1962	M-S	\$498,750.
43,000	conv. 4s. ....			1955	J-D	39,022.50
50,000	A. T. and S. Fe. gen. 4s. ....	*		1995	A-O	50,056.25
50,000	Balto. & Ohio R. R. ref. 4s. ....			1941	M-N	46,875.
100,000	" " " " 1st Mtg. 5s. ....	*		1948	JAJO	105,500.
100,000	" " " " gen. and ref. 5s. ....	*		1995	J-D	102,416.67
50,000	" "					



*Schedule of Securities—Continued*

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Public Utility</i>					
\$100,000	Ala. Power Co. 1st & ref. 4½s. ....			1967	J-D	\$87,265.
212,000	Ala. Power Co. 1st & ref. 5s. ....			1968	M-S	202,322.50
175,000	Am. Tel. & Tel. Co. deb. 3¼s. ....			1961	A-O	176,750.
190,000	Am. Tel. & Tel. Co. deb. 3¼s. ....			1966	J-D	193,800.
125,000	Am. Tel. & Tel. Co. sink. deb. 5½s. ....			1943	M-N	130,260.62
300,000	Appalachian Electric Power Co. 1st ref. 5s. ....			1956	M-N	296,125.
300,000	Ark. P. & L. Co. 5s. ....			1956	A-O	292,312.50
150,000	Bell Tel. Co. of Canada 1st 5s. ....			1955	M-S	154,593.75
100,000	Bell Tel. Co. of Canada 1st 5s. ....			1957	J-D	101,125.
300,000	Birmingham Electric Co. 1st ref. 4½s. ....			1968	M-S	283,056.25
75,000	Blackstone Valley Gas & E. 4s. ....			1965	M-N	76,875.
300,000	Carolina Power & L. Co. 1st & ref. 5s. ....			1956	A-O	302,298.75
110,000	Cedar R. Mfg. & P. Co. 1st sink. 5s. ....			1953	J-J	109,560.50
380,000	Columbia Gas and Elec. Corp., deb. 5s. ....			1961	J-J	379,762.50
300,000	Columbus Rwy., P. & L. 4s. ....			1965	M-N	304,600.
77,000	Comm. Edison, 1st Mtg. 5s. ....			1954	J-D	82,660.15
158,000	Comm. Edison, 1st Mtg. 4s. ....			1981	M-S	115,465.49
32,000	Consolidated Edison Co. of N. Y. deb. 3¼s. ....			1956	A-O	31,840.
100,000	Detroit Edison gen. & ref. 4s. ....			1965	A-O	103,500.
250,000	Gatineau Power, 1st 5s. ....			1956	J-D	248,958.33
325,000	Georgia Power Co. 1st ref. 5s. ....			1967	M-S	320,112.50
200,000	Gulf States Util. Co. 1st mtg. & ref. 4s. ....			1966	A-O	206,000.
90,000	Hackensack Water Co., Gen. & Ref. 5½s. ....			1977	J-J	97,243.75
100,000	Houston Ltg. & Power Co. 1st mtg. 3½s. ....			1966	J-D	103,000.
100,000	Idaho Power Co. 1st 5s. ....			1947	J-J	100,750.
200,000	Illinois P. & L., 1st & ref. 5s. ....			1956	J-D	196,750.
200,000	Indianapolis P. & L. 1st 5s. ....			1957	J-J	198,806.25
200,000	Ind. & Mich. Elec. Corp., 1st ref. 5s. ....			1955	M-S	202,182.50
300,000	Inter. Tel. & Tel. deb. 4½s. ....			1952	J-J	288,250.
280,000	Int. Rap. Trans. ref. 5s. ....	*		1966	J-J	276,701.
100,000	Iowa Southern Utilities Co. 1st & ref. 5½s. ....			1950	M-N	100,474.66
88,000	Louisiana Power & Light Co. 1st 5s. ....			1957	J-D	90,420.
300,000	Memphis P. & L., 1st & ref. 4½s. ....			1978	A-O	279,250.
100,000	Metropolitan Edison Co. 1st 4½s. ....			1968	M-S	109,470.
300,000	Milwaukee E. R. & L. ref. & 1st 5s. ....			1961	J-D	302,337.50
100,000	Minnesota P. & L. 1st & ref. 4½s. ....			1978	M-N	92,156.25
50,000	Monongahela West Penn. Pub. Serv. Co. 1st & gen. 4½s. ....			1960	A-O	52,000.
100,000	Montana Power Co., 1st & Ref. 3¼s. ....			1966	J-D	101,000.
52,000	New Eng. Tel. & Tel. 5s. ....			1952	J-D	51,748.
100,000	New Orleans Pub. S. 5s. ....			1955	J-D	99,200.
65,000	N. Y. & Westchester Ltg. 5s. ....			1954	J-J	67,052.50
300,000	New York P. & L., 1st 4½s. ....			1967	A-O	286,125.
150,000	Northern Ind. Pub. S., 1st ref. 5s. ....			1966	M-N	152,887.50
50,000	Northern States Power Co., 1st & Ref. 3½s. ....			1967	F-A	47,500.
100,000	Ohio Edison Co. 1st & Cons. 4s. ....			1965	M-N	100,500.
175,000	Ohio Power Co., 1st and ref. 4½s. ....			1956	J-D	163,439.06
100,000	Ohio Public Serv. Co., 1st Mtg. 4s. ....			1962	F-A	102,625.
50,000	Ohio Public Serv. Co., 1st & Ref. 6s. ....			1953	M-S	54,455.
200,000	Okla. G. & E. 1st 3¼s. ....			1966	J-D	205,000.
100,000	Pac. G. & E. Co., 1st & ref. 3¼s. ....			1961	J-D	102,500.
100,000	Pac. G. & E. Co., 1st & ref. 4s. ....			1964	J-D	104,000.
200,000	Penn. Electric Co., 1st & Ref. 5s. ....			1962	A-O	203,882.50
300,000	Penn. Power & L. Co., 1st mtg. 4½s. ....			1981	A-O	289,562.50
105,000	Penn. Water & Power Co., 1st ref. 4½s. ....			1968	M-S	102,597.06
136,000	Pub. Serv. Co., of Indiana, 1st & ref. 6s. ....			1952	F-A	112,540.
70,000	Pub. Serv. Co., of No. Ill. 1st Lien & Ref. 4½s. ....			1981	A-O	66,655.
160,000	Pub. Serv. Co., of No. Ill., 1st ref. 5s. ....			1956	A-O	157,550.
60,000	Puget Sound Power & L. 1st & ref. 4½s. ....			1950	J-D	56,550.
50,000	Puget Sound Power & L. 1st & ref. 5½s. ....			1949	J-D	31,900.
75,000	Rochester Gas & Elec. Corp. gen. 5s. ....			1962	M-S	69,475.
9,565,000	Forward.....					9,417,679.87

*Schedule of Securities—Continued*

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
<i>Public Utility</i>						
\$9,565,000	Brought Forward.....					\$9,417,679.87
250,000	Shawinigan W. & P. Co., 1st & coll. 4½s.			1967	A-O	238,510.42
75,000	So. Bell Tel. & Tel. Co. Deb. 3¼s.			1962	A-O	72,375.
200,000	So. Calif. Edison Co., 1st & ref. 3¼s.			1960	J-J	197,000.
125,000	Tenn. E. & P. 1st & ref. 5s.			1956	J-D	127,037.50
300,000	Texas Electric Service, 5s.			1960	J-J	292,700.
200,000	Texas Power & Light Co., 1st & ref. 5s.			1956	M-N	205,143.75
120,000	Toledo Edison 1st. Mtg. 5s.			1962	M-N	115,800.
250,000	Union Elec. Co. of Missouri, 1st. Coll. Trust 3¼s.			1962	J-J	249,537.50
220,000	Utah L. & T. Co., ref. 5s.			1944	A-O	215,193.
300,000	Virginia Elec. & Power Co. 1st & ref. 4s.			1955	M-N	303,750.
235,000	Washington Water Power Co., 1st & gen. mtg. 5s.			1960	J-J	237,496.87
100,000	Western United Gas & Electric Co., 1st Mtg. 5½s.			1955	J-D	105,187.50
11,940,000	Public Utility Sub-Total.....					11,777,411.41
<i>Mortgages</i>						
25,000	Empire Title and Guarantee Co., Guarant- eed 1st Mortgage, Ctf. No. 1676 5%...	*		1939	FMAN	25,000.
100,000	Lawyers Mtg. Co. Guaranteed 1st Mtg. Ctfs., Series 18397 5½%.....	*		1935	J-J	100,000.
80,000	Lawyers Title and Guaranty Co., 5½% Mortgage.....	*		1935	A-O	80,000.
100,000	Guaranteed 1st Mortgage 1184 Cromwell Ave., N. Y. 5½%.....	*		1932	M-S	99,000.
100,000	Guaranteed 1st Mtg. N. W. cor. Westbury Ct. & Flatbush Ave., Brooklyn 5½%...	*		1933	M-N	100,000.
90,000	N. Y. Title and Mtg. Co. Guaranteed 1st Mtg. Ctf., 5½%.....	*		1938	A-O	90,000.
100,000	N. Y. Title and Mtg. Co. Guaranteed 1st Mtg. 4½%.....	*		1940	J-D	100,000.
100,000	Title Guarantee and Trust Co. 1st Mtg. Ctf. 130057 3% Participating.....	*		1939	J-D	100,000.
695,000	Mortgages Sub-Total.....					694,000.
<i>Industrial</i>						
25,000	Addressograph-Multigraph Corp. Deb. 5½s			1945	A-O	25,000.
50,000	Allis-Chalmers Mfg. Co., Conv. Deb. 4s.			1952	M-S	51,587.
100,000	American I. G. Chemical Corp., conv. 5½s			1949	M-N	105,861.25
50,000	American Radiator Co., Deb. 4½s.			1947	M-N	49,125.
99,000	Bethlehem Steel Corp. Cons. sink. fund 4½s			1960	J-J	97,515.
6,000	Phelps Dodge Corp. Conv. Deb. 3½s.			1952	J-D	6,000.
200,000	Rwy. Express Agency, 5s.			1939-48	M-S	200,000.
100,000	Remington Rand Inc., Deb. 4¼s.			1956	M-S	100,162.50
130,000	Scovill Manufacturing Co., Conv. Deb. 5½s			1945	J-J	131,831.67
250,000	Shell Union Oil Corp., Deb. 3½s.			1951	M-S	247,500.
100,000	Socony Vacuum Oil Co. Deb. 3½s.			1950	A-O	100,000.
53,000	Southern Kraft Corp., 1st. leasehold & gen. mtg. 4¼s.			1946	J-D	51,790.
1,975,000	Tenn. C. I. & R. Co. 5s.			1951	J-J	1,975,000.
100,000	Texas Corp., Deb. 3½s.			1951	J-D	100,000.
85,000	Wheeling Steel Corp., 1st Mtg. 4½s.			1966	F-A	86,275.
100,000	Youngstown S. & Tube 1st Mtg. sink. 4s.			1961	M-N	98,500.
3,423,000	Industrial Sub-Total.....					3,426,147.42

*Schedule of Securities—Continued*

Aggregate— Par or Nominal Value	Description	Registered		Ma- turity	Int. Due	Total Cost or Value at Date Acquired
		Princ. Int.	Princ. Only			
	<i>Foreign</i>					
\$120,500	German External Loan of 1924 7s. ....			1949	A-O	\$128,738.53
115,000	Imp. Japanese Govt. 5½s. ....			1965	M-N	103,212.50
300,000	Kingdom of Denmark, ext. 4½s. ....			1962	A-O	274,375.
25,000	City of Montreal 5s. ....			1956	M-N	24,062.50
75,000	City of Montreal sink. 5s. ....			1954	M-N	72,375.
100,000	City of Montreal 4½s. ....			1946	F-A	94,368.90
192,000	New South Wales, ext. 5s. ....			1958	A-O	181,980.
100,000	Province of Alberta deb. 4½s. ....			1958	J-J	93,750.
100,000	Province of Alberta 5s. ....			1950	A-O	101,150.
200,000	Province of Manitoba deb. 4½s. ....			1958	A-O	190,515.70
100,000	Province of Nova Scotia 4½s. ....			1952	M-S	100,312.50
100,000	Province of Ontario 4s. ....			1964	M-N	87,150.10
100,000	Province of Ontario 5s. ....			1959	M-N	99,789.63
40,000	Province of Ontario 6s. ....			1943	M-S	43,137.50
30,000	Prov. of Saskatchewan deb. 5s. ....			1943	J-D	30,627.44
100,000	City of Toronto con. deb. 5s. ....			1949	J-D	96,164.59
90,000	City of Toronto, 5s. ....			1952	J-D	89,333.53
50,000	City of Winnipeg inter. deb. 5s. ....			1943	J-D	48,250.
50,000	City of Winnipeg deb. 6s. ....			1946	A-O	53,500.
100,000	City of Winnipeg deb. 4½s. ....			1946	J-D	95,375.
2,087,500	Foreign Sub-Total. ....					2,008,168.42
	<i>State and Municipal</i>					
50,000	City of Cleveland, Water Works, 5½s. ....			1967	M-N	52,984.60
25,000	City of Detroit, Water Supply, 4s. ....			1955	J-D	24,812.50
25,000	City of Detroit, Water Supply, 4½s. ....			1952	M-S	25,250.
50,000	City of Newark, Street Opening, 5¼s. ....			1958	F-A	51,724.94
50,000	City of New York, 4¼s. ....			1977	J-J	59,250.
50,000	City of New York, 4½s. ....			1979	J-D	51,750.
84,000	State of North Carolina, Highway, 4½s. (\$30,000 registered) ....	*		1953-63	J-J	92,819.50
50,000	City and County of San Francisco, Hetch Hetchy, 5¼s. ....			1960	J-D	53,523.34
384,000	State and Municipal Sub-Total. ....					412,114.88
31,527,500	BONDS—Funds Invested. ....					30,918,522.46
Number of shares					Divds. Due	
	<i>Preferred Stocks</i>					
500	A. T. & S. Fe pref. stock. ....				F-A	52,125.
31	Caterpillar Tractor Co., Cum. pref. ....				FMAN	3,100.
2,000	Cons. Edison Co. Cum. pref. stock. ....				FMAN	198,725.
1,000	Du Pont de Nemours, deb. Stock. ....				JAJO	116,125.
500	J. I. Case Thresh. M. Co. pref. stock. ....				JAJO	62,225.
1,000	Northern States Power Co., Cum. pref. ....				JAJO	103,000.
400	Union Pac. R. R., pref. stock. ....				A-O	33,415.
5,000	U. S. Steel Corp., pref. stock. ....				MJSD	715,173.50
10,431	Preferred Stocks—Sub-Total. ....					1,283,888.50

*Schedule of Securities—Continued*

Number Shares	Description	Total Cost or Value at Date Acquired
<i>Common Stocks</i>		
1,000	Air Reduction Company . . . . .	\$69,855.
1,113	Allis-Chalmers Manufacturing Co. . . . .	55,667.50
700	Alpha Portland Cement Co. . . . .	24,530.
330	American Brake Shoe and Foundry Co. . . . .	15,895.
1,200	American Cyanamid Co. . . . .	39,255.
2,800	American Radiator & Standard Sanitary Corp. . . . .	67,542.50
1,500	Bethlehem Steel Corp. . . . .	117,325.00
2,600	Borg Warner Corp. . . . .	102,642.50
1,200	Caterpillar Tractor Co. . . . .	97,855.
1,000	Chrysler Corporation . . . . .	118,065.
1,000	Commercial Investment Trust Corp. . . . .	73,047.50
400	Consolidated Edison Co., of N. Y. . . . .	18,355.
400	Continental Can Co. . . . .	30,452.50
508	Continental Insurance Co. . . . .	20,285.30
2,300	Continental Oil Corp. . . . .	83,732.50
200	Dow Chemical Co. . . . .	28,950.
200	Eastman Kodak Co. . . . .	34,450.
1,700	General Electric Co. . . . .	79,450.
1,500	General Motors Corporation . . . . .	103,550.
900	W. T. Grant Co. . . . .	40,397.50
700	Gulf Oil Corp. . . . .	40,275.63
200	Hartford Fire Insurance Co. . . . .	15,462.94
300	Humble Oil & Refining Co. . . . .	20,240.
100	Ingersoll-Rand Company . . . . .	13,425.
720	Inland Steel Company . . . . .	75,010.
105	International Business Machines Corp. . . . .	18,275.
1,300	International Harvester Co. . . . .	122,972.50
1,700	International Nickel Co. . . . .	101,187.50
413	Johns-Manville Corp. . . . .	53,925.
1,900	Kennecott Copper Corp. . . . .	94,155.
800	Monsanto Chemical Co. . . . .	75,940.
1,230	Montgomery Ward & Co. . . . .	72,223.63
400	Mortbon Corp. of N. Y., V. T. C. for Class A Cap. Stock. . . . .	28,070.
1,000	National Lead Co. . . . .	46,290.
800	Newberry Co. (J. J.) . . . . .	58,737.50
700	New Jersey Zinc Co. . . . .	61,400.
800	Owens-Illinois Glass Co. . . . .	117,197.50
1,200	Penney Co., (J. C.) . . . . .	64,995.
1,600	Phelps Dodge Corp. . . . .	64,340.25
500	Pittsburgh Plate Glass Co. . . . .	17,902.50
300	Procter & Gamble Co. . . . .	41,972.50
700	Pullman, Inc. . . . .	57,662.50
1,000	St. Joseph Lead Co. . . . .	106,337.50
1,290	Sears Roebuck & Co. . . . .	51,651.13
400	Sherwin-Williams Co. . . . .	69,165.
1,600	Standard Oil Co., of California. . . . .	125,720.
1,900	Standard Oil Co., of N. J. . . . .	89,824.13
1,867	Texas Corporation. . . . .	29,463.89
50	Travelers Insurance Co. . . . .	52,570.
600	Underwood Elliott Fisher Co. . . . .	114,977.50
1,200	Union Carbide & Carbon Co. . . . .	97,615.
900	United States Gypsum Co. . . . .	92,360.
900	United States Steel Corp. . . . .	12,587.75
300	Westinghouse Air Brake Co. . . . .	61,262.50
500	Westinghouse Electric & Mfg. Co. . . . .	108,879.75
1,520	Youngstown Sheet & Tube Co. . . . .	
54,046	Common Stocks—Sub-Total . . . . .	3,495,361.90
64,477	Common and Preferred Stocks—Funds Invested . . . . .	4,779,250.40
	Aggregate Investments (Bonds and Stocks) . . . . .	35,697,772.86



# Real Estate and Equipment, Original Cost

## Administration (October 31, 1937)

### Washington, D. C.

Building, site, and equipment.....		\$414,158.29
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## Division of Plant Biology (September 30, 1937)

### Palo Alto, California (Headquarters)

Buildings and grounds.....	\$154,786.71	
Laboratory.....	54,012.12	
Library.....	29,209.31	
Operating appliances.....	25,477.72	263,485.86

## Department of Embryology (September 30, 1937)

### Wolfe and Madison Sts., Baltimore, Maryland

Library.....	3,350.74	
Laboratory.....	14,153.22	
Administration.....	7,298.99	24,802.95

## Department of Genetics (September 30, 1937)

### Cold Spring Harbor, Long Island, New York

Buildings, grounds, field.....	292,361.49	
Operating.....	31,376.83	
Laboratory apparatus.....	28,805.21	
Library.....	45,508.28	
Archives.....	45,488.90	443,540.71

## Geophysical Laboratory (September 30, 1937)

### Upton St., Washington, D. C.

Building, library, operating appliances.....	223,835.56	
Laboratory apparatus.....	155,508.51	
Shop equipment.....	19,148.19	398,492.26

## Division of Historical Research (September 30, 1937)

### Administration Building, Washington, D. C.

Operating.....	21,372.77	
Library.....	8,326.93	29,699.70

## Tortugas Laboratory (September 30, 1937)

### Tortugas, Florida

Vessels.....	30,930.43	
Buildings, docks, furniture, and library.....	12,030.86	
Apparatus and instruments.....	9,322.55	53,183.84

## Department of Meridian Astrometry (September 30, 1937)

### Dudley Observatory, Albany, New York

Apparatus and instruments.....	4,846.84	
Operating.....	5,273.68	10,120.52

## Nutrition Laboratory (September 30, 1937)

### Vila St., Boston, Massachusetts

Building, office, shop, and library.....	133,542.13	
Laboratory apparatus.....	37,105.54	170,647.67

## Mount Wilson Observatory (September 30, 1937)

### Pasadena, California

Buildings, grounds, road, and telephone line.....	225,056.75	
Shop equipment.....	46,477.04	
Instruments.....	668,455.28	
Furniture and operating appliances.....	204,273.14	
Hooker 100-inch reflector.....	608,428.52	1,752,690.73

## Department of Terrestrial Magnetism (September 30, 1937)

### 5241 Broad Branch Road, Washington, D. C.

Building, site, and office.....	229,139.22	
Survey equipment.....	103,396.40	
Instruments, laboratory, and shop equipment.....	198,712.30	531,247.92

4,092,070.45





REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1937







Winkler  
May 11. 1925

Winkler

# REPORT OF THE PRESIDENT

## OF THE

# CARNEGIE INSTITUTION OF WASHINGTON

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In accordance with regular procedure, the President has the honor to transmit to the Trustees of Carnegie Institution of Washington the following report on problems and activities of the Institution in the year ending October 31, 1937.

One of the most effective means for estimating the importance of Elihu Root to the Carnegie Institution is found in noting the extent of his influence upon policies and activities during those later years in which it was no longer possible for him to attend meetings of the Board and Executive Committee. **Elihu Root** At no time during this period of his absence from the administrative offices or from the council room was any major question discussed without reference to policies or opinions representing Mr. Root's point of view. So, it came about that with the passing of Elihu Root, on the seventh of February, 1937, a relation which had obtained since the founding of the Institution in 1902 continued as an established influence upon the objectives and policies of the Institution.

At the time of his separation from us, Mr. Root was the only surviving member of the original Board of Trustees, and was the only person fully acquainted with the ideals and purposes expressed by Mr. Carnegie in founding the Institution. In his relation to the administration Mr. Root served as a member of the Executive Committee from 1902, as Vice-Chairman of the Board

CARNEGIE INSTITUTION OF WASHINGTON

from 1903 to 1912, and as Chairman from 1913 to 1937. These contacts gave him complete acquaintance with the administrative and scientific activities from the beginning. Through this touch with the program he had full appreciation of factors which had made it important on one hand to maintain those activities and objectives the soundness of which time and experience had tested, or, on the other side, to recognize the elements which might be allowed to follow well-defined lines of evolution toward fields quite different from those originally visualized.

The fact that Mr. Root had full knowledge of ideals, objectives, policies, administration, effective progress in fundamental research, and concerning the meaning of the Institution in terms of public relations may not be considered as due alone to long and close touch with the program of work. The high qualities of intellect and interest, coupled with broad vision and ability to determine the essential elements of complicated situations, which distinguished him as the foremost citizen of America, made it possible for Mr. Root to evaluate the objectives, organization, and accomplishments of the Institution. His vision over the whole field of the Institution's work, past and present, was so clear, and his appreciation of human questions involved so unusual, that discussion of any problem brought help to the Board and to the Administration.

Mr. Root's interest in and understanding of what might be accomplished through any field of research was always an exceptional stimulus to investigators and to the Administration, and yet this influence was exerted without the danger of becoming lost in details or of failure to recognize that careful research is the method by which fundamental truths are discovered and verified.



In conducting business of the Institution, whether concerning matters of finance, organization, outside relationships, or plans for a research, Mr. Root's thought was always direct, and his judgments determined by uncompromising adherence to principles which human experience had shown to be the most reliable. Were it not that this was known to be his established method of procedure, one might have been inclined to think that in treatment of problems concerning the search for scientific truth, the unvarying acceptance of realities and what they imply as seen in science had come to have an influence on research administration. Actually the conditions described were those under which administration of research was itself held to consistent support of precision and truth, whether in financial arrangements, organization, or in the methods by which investigations were advanced.

In development of the many fields of activity represented within the Institution, Mr. Root's interest was always keen, whether the problem concerned atomic physics, geologic time, the significance of chromosomes or genes, historical research, or certain of those fields of investigation in which science and the humanities may combine to mutual advantage. Mr. Root was an ardent supporter of the idea that the Carnegie Institution should be so organized as to permit mutual aid among the projects or departments, as well as between the groups of the Institution and other comparable agencies. In some measure progress of certain Institution researches in recent years has been made possible through his support of this view.

Following the principle concerning importance of quality in personnel advocated by Mr. Carnegie, Mr. Root gave his support consistently to selection of the best type

CARNEGIE INSTITUTION OF WASHINGTON

of man, as also to what seemed the most significant type of problem. At the same time he supported the view that good men and good problems must have good organization and good environment, both mechanical and human, if the highest success is to be attained.

Although insistent in support of the idea that institutions devoted to research have a primary responsibility for advancement of knowledge, Mr. Root maintained also the importance of recognizing responsibility on the part of the Institution for making the results of its investigations available in easily interpretable form for use by the world of science, by engineering, for general application, and for understanding by the people. It was his view that the continuing advance of science depends in considerable measure upon offering to the public opportunity to educate itself with reference to the accomplishments of research regarding the fundamental nature of the world of things about us, as well as of man himself.

In his later years, Mr. Root often referred to the fact that among the problems which seem to have increasing importance, one of the most significant concerns the need for making sure that the fundamental elements derived from major scientific advances are so interpreted and presented that they may become embedded in the thought of the people. Without such handling of the materials of science Mr. Root considered that the rate of progress might be slow and the advance of civilization perhaps impeded.

The attitude of Mr. Root toward interpretation of results of research is well illustrated by comment which he made some years ago at the end of an Executive Committee meeting devoted to discussion of administrative

detail. Having finished the work which required a vote of the Executive Committee, Mr. Root drew back his chair and said, "We will now consider matters which represent more fundamental responsibilities of the Institution," and for a half hour discussed the desirability of making the public acquainted with some of the most interesting and important discoveries in study of the spiral nebulae, ending with the comment, "If such things could be interpreted to the public in simple form, it would be worth half of the total expenditure of the Institution." He gave his enthusiastic support to the attempt to plan carefully prepared public lectures, conferences, and exhibits, and on one occasion remarked with particular reference to functions of a proposed addition to the Administration Building for use in public relations, "You will be carrying out some of the purposes of the Institution in which Mr. Carnegie was especially interested."

While, then, we miss the immediate companionship, support, and stimulus of the man who through this long period helped so faithfully and effectively to carry out the purposes which led Mr. Carnegie to found the Institution, we may yet say that his influence will continue to be felt, and his voice to be heard, through the coming years however far they may stretch.

Through the death of Andrew W. Mellon on August 26, 1937, the Institution lost one of the most distinguished members of its Board of Trustees. Although  
**Andrew W.  
Mellon** deeply interested in the work and problems of the Institution during the period of his membership in the Board, from 1924 to 1937, the requirements of public office to which he was called pre-

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vented Mr. Mellon from giving to affairs of the Institution the time and thought which he had wished to contribute. Mr. Mellon was, however, always an interested student of our problems and a wise counselor on critical questions. Through his aid to many agencies he made an extremely significant contribution to the advance of knowledge, research, and culture in the widest sense, and many of these activities were closely related to major projects of the Institution.

In the search for interpretation of certain characteristic present-day conditions, investigational activities of recent years have placed such emphasis upon the relation of science to the processes of social evolution that a considerable literature on the subject has developed. Examination of the many suggestions made indicates general agreement with the idea that the influence of science upon society is not in any sense comparable to the kind of effect produced by purely physical laws. The farther we advance in consideration of the problem, the clearer it is that the answer will be obtained only after we have a thorough understanding of the content and mode of development in science, of the structure and mode of evolution of society, of the manner in which new facts presented by science are absorbed, and of the ways in which the methods of science are adapted to processes of human thought.

It is necessary that within the field of science we know the degree of complexity in organization and classification of subjects. It is equally important in society not merely to have appreciation of the difficulties in interpretation of the influence of science, but to attain a degree of

awareness of interdependence among social elements comparable to our understanding of the interrelation among elements involved in the unity of nature.

In advance of science, just as in affairs of everyday life, attainment of success involves that balance of judgment which brings to bear both knowledge of details and the kind of vision which gives perspective comprising all the factors involved. Even infinite patience in gathering details may lead only to accumulation of multitudes of facts the possession of which will have little significance. So, looking in the other direction, construction of elaborate classification schemes and formulation of comprehensive theories may have small value in absence of intimate acquaintance with basic details.

We consider that science is advanced when a previously unknown fact or a new item of information is located and described. Subsequent history may show that the utilization of the fact with relation to other knowledge, or its application for the benefit of mankind, may be delayed to a period far beyond the time in which the greatest emphasis is placed upon the discovery. When, at some later day, the item of knowledge is put in its place with relation to other materials, this useful contribution may be considered greater than that represented by the original discovery.

The formulation of great hypotheses, or of theories, or of points of view concerning interrelation of elements in the field of knowledge may be seen as something of exceptional importance in the advance of science or of civilization. But often we place larger emphasis on mere discovery of isolated elements. Again, we give high measure of approbation to utilization of new information,



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either through isolated facts or as representing points of view, when applied in such manner as to better the position of human kind with reference to maintenance of life, to advancement of individual interests, or to appreciation and enjoyment of values in living. In the forward march of science and civilization we seem to pass through periods in which we are concerned with intensive delving for facts or materials or items considered important in themselves. At other times we direct attention toward organization of these materials into patterns of special human significance.

Periods of exceptional stress, such as the Great War, or the recent depression, tend to emphasize reorganization of materials in such manner as to contribute the maximum toward betterment of the situation for mankind. In the middle and late stages of the recent depression large contribution has been made in this country toward reorganization of knowledge, formulation of new views, and establishment of new institutions in the interest of human betterment. Science has been drawn upon largely to aid in working out these plans for reorganization, but seemingly some of the greatest difficulties have concerned attainment of proper balance between details involved and the theoretical conception, or between the conception and its human application. Perhaps the lessons taught by this experience will help to point the way toward better appreciation of balance in organization involving both science and the various forms of its application.

The much-desired cooperation among students of human affairs through joint effort of workers in the fields of the natural and social sciences, such as economics



and government, has seemed less easy of realization than was perhaps expected. There can be no doubt that certain of the attitudes and methods of science appear difficult to use in application to human relations, and that the methods applied so directly in the natural sciences often seem inadequate in research upon our vastly complicated human questions. There are, however, many aspects of research procedure developed in the natural sciences which will have increasing value in application, either directly or indirectly, through various phases of the social sciences.

There is importance in the idea that while in certain aspects of natural science, as in physics and chemistry, one seems to deal with immutable or fixed laws, the factors presented for consideration in social science broadly, or in economics, shift so frequently that the methods of natural science can be applied only with difficulty. It is, however, well to remember that problems in biology also show us a situation in which changing conditions, and apparently changing factors, present one of the recognized features in any investigation. The larger history of evolution in life-forms gives one of the best illustrations of continuous change, and yet these changes seem to depend upon fundamental laws which may continue in operation much as in physics or chemistry while new factors come and others go. The general principle of evolution rests upon conservation of certain features which might be called fundamental, and continuous shift in others leading to production of new situations or features which may bring about what we call creation.

In the rapid shift of human affairs, conditions, opportunities, and obligations change so rapidly that we may

tend to view the laws of conduct as themselves changing fundamentally. So we seem almost to find in international diplomacy a new statement of human obligations, and a new interpretation of principles which have had general recognition among individuals over the world. And yet, we may have faith that things which are looked upon as representing the principles of right and honesty will in the end prevail. Perhaps neglect to appreciate this point of view is responsible for some of the difficulty in the world at the present time.

It is also to be borne in mind that we must not only recognize the principle of change or evolution in whatever relates to life, but we must give recognition to the principle of constructive or creative activity developing in the peculiar types of creatures known as human beings. But creative activity does not rest upon a breaking down of law. It is a natural expression of certain laws through means which make evolution and the development of new elements possible.

Orderly movement in social evolution probably depends in considerable measure upon our ability to determine the balance which should obtain among certain factors which represent immutable laws, others which we find leading to evolutionary development, and still other features in human life which have to do with constructive or creative activity. Such matters may become of great importance in the future.

One aspect of this problem, which seems often to be misunderstood, has to do with the influence of science upon society in the sense of utilization of facts merely as facts, and not as parts of a wider scheme of knowledge. It is possible to bring extreme confusion into human

affairs through the use of facts. This may be illustrated when on two sides of a legal case opposing talent uses scientific information, but in each case covering only a part of the evidence. Facts are used, but not all of the facts, and such situations make controversy possible. It has been said that truth differs from fact in that truth represents all of the facts, or, as is said commonly, all of the truth, so set up as to give a clear picture of what exists. It has also been said that honesty is the expression of fact or of the truth as involved in discussion of human relations.

One illustration of a way in which science is held to affect present-day thought is found in the suggestion that research tends to diminish the interest of mankind in the world of nature about us, which is the principal field of scientific activity. This is in spite of the fact that we are practically embedded in nature, and that much of man's philosophy of life in past centuries has based itself upon observations concerning the character of the world in which we live and our relation to it.

**Science and  
Appreciation  
of Nature**

The argument in favor of the view that there is diminishing interest in nature on the part of modern man rests in considerable part upon the idea that present-day tendencies look toward shift of human appreciation to results of mechanization in the world, or in the life of man, by reason of advances in science. It has been thought that jazz, the radio, the automobile, and many other contributions of present-day thinking have turned interest away from the elements of nature and that, considered broadly, mankind of today transfers its attention to the varied, and often mechanized, activities of man,

rather than to direct it toward the tremendous range of evidences of creation in the world about us.

If it be true that the coming of science has diminished interest in the values of nature, serious harm has been done. Much of our reverence and religion of the past had its origin in what we knew of the world of nature, and much of the soothing influence exerted upon man through his environment has been derived from the appeal of the natural world and love of its beauty. It is, therefore, a matter of great human importance to consider whether the influence of science in this respect is really detrimental.

Whatever argument is presented on one side or another of this question will almost inevitably become complicated, but it is important at the moment to call attention to the fact that with the extension of our knowledge of the universe through science in all directions, by the telescope into the infinite spaces inhabited by spiral nebulae, by the microscope into the infinite littlenesses of the world of bacteria and molecules, or by the student of history through the vast reaches of time, we have come to see the world as almost infinitely elaborated, and yet having all of its parts intimately related. Therefore we think with some assurance on the idea of unity of nature. At the same time we have seen movement of the world through the ages develop that aspect of being which we call evolution, producing further developments, not only more complicated, but which we consider more advanced than those of preceding periods. So, seen in the light of the broader reach of science, the universe about us becomes more complex and more wonderful, and yet more dependable, more clearly creative, and more beautiful. And question may well be

raised whether the influence of science through interpretation of the world in which we live does not tend to advance or develop our interest in nature and appreciation of it more rapidly than the elements of mechanization tend to turn our attention away from nature and largely toward the present-day works of man.

### GEOPHYSICAL INVESTIGATIONS

Prior to the establishment of the Geophysical Laboratory there had been little opportunity to make exact measurements on the formation of the minerals that constitute the crust of the Earth. Just what happened when a crystalline rock melted, or when a molten magma solidified, was largely a matter of conjecture. Volcanic outbursts, world-shaking earthquakes, and other phenomena having to the untrained mind a hint of the supernatural, resisted explanation because of the lack of experimental facts. The segregation of ores and minerals, so necessary for the well-being and higher civilization of mankind, involved properties and processes of which little was known. The purpose of such research since its beginning has been to study and to measure the factors that enter into the formation of rocks and the other materials of the Earth. Although there have been some changes in scope and methods, the general objective continues to be the determination, with all the precision that may be possible, of the underlying causes of geologic and geophysical phenomena.

In commenting upon the work in his annual report Dr. L. H. Adams, Acting Director of the Geophysical Laboratory, states the problem as follows:



“Upon encountering a broad problem in geology, it appears necessary first to formulate it in terms of a series of sharply defined problems in physics and chemistry. Adherence to this procedure is based on the conviction that the present condition of the Earth, however it may have been attained, is the result of orderly processes which, except in magnitude of space and time, have their exact counterpart in experiments that can be performed at will in the laboratory. Whatever success the Laboratory may have achieved in experimental geology has resulted from adherence to the quantitative method of approach and a recognition of the necessity of measuring simple factors. In this as in other branches of science a major purpose is the discovery of generalizations or ‘laws’ which, by presenting a vast array of information in a compact and usable form, make it possible for the human mind to comprehend matters of forbidding complexity and even to predict the course of processes that have not yet been subjected to measurement.

“Progress in geophysical investigations requires a judicious combination of field work and laboratory experimentation. On the laboratory side a study of the melting temperatures of mixtures containing the important rock-forming minerals has been carried forward successfully during the year. The systems containing alkali-alumina silicates have proved to be of unusual interest. It has already been established that in the solidification of molten mixtures containing the feldspathoid, leucite, with silica and either diopside or anorthite, the diopside or anorthite is first removed nearly completely by crystallization, leaving a residual liquid of nearly pure alkali-alumina silicate. The alkali-alumina systems are re-



markable also for the length of time required for their investigation. Owing to the slowness with which the crystallization of the materials proceeds, the separate researches may require five years or more for completion. The effect of water as an ingredient of silicate melts is now receiving more active attention. Among the significant results already obtained with a new apparatus for quenching silicate mixtures in steam under pressure is the establishment of the temperature at which analcite is transformed to albite. With a starting material intermediate in composition between analcite and albite this temperature is  $385^{\circ}$  C. Other investigations with an apparatus that develops pressure corresponding to a depth of 13 km., or 8 miles, below the surface of the Earth have shown that the melting point of albite in the presence of water is lowered from  $1125^{\circ}$  C. to  $810^{\circ}$  C. at 3000 atmospheres. . . .”

Field studies and related laboratory investigations have covered a variety of interesting regions. Special mention should be made of the study of volcanic activity in Guatemala and El Salvador, which has thrown light on the chemical aspects of volcanism and has demonstrated the remarkable amount of hydrofluoric acid contained in some volcanic gases; the investigation of rocks from Antarctica, collected by the Second Byrd Antarctic Expedition, which showed some unusual features and have lent themselves well to a careful measurement of the separate compositions of groundmass and phenocrysts; the securing of additional cores from the ocean bottom at depths greater than had been reached previously; and the measurement of gravity with a new portable apparatus, sensitive to one part in a million, which has shown the

existence of striking differences in gravity over small distances along the surface.

### TERRESTRIAL MAGNETISM

A major advance in the terrestrial-magnetic research is reported by Dr. John A. Fleming, Director of the Department of Terrestrial Magnetism. This comprises establishing proof, in cooperation with Mount Wilson Observatory and other organizations, of the association of a special type of magnetic disturbance and sharp fade-outs of high-frequency radio-wave reflections with bright eruptions in the solar chromosphere.

In referring to this achievement Dr. Fleming reports: "These effects are propagated from the Sun to the Earth with the velocity of light. The active agent is believed to be ultra-violet light originating in the solar eruption, which produces sudden and intense electrification of the Earth's upper atmosphere. Previously the view was generally accepted that no *direct* correspondence exists between observable solar and terrestrial magnetic phenomena. These new effects serve to discriminate between various theories of terrestrial-magnetic changes and supply evidence on the electrical processes taking place in the ionosphere. The discovery that the phenomena of radio fade-out are related to a magnetic effect of the diurnal-variation type is a definite advance toward the ultimate objective of the ionospheric investigations. The determination of the heights at which this effect occurs was made possible through the program of automatic recording at the observatories. The high ionization produced below the lower *E*-region of the ionosphere by

bright chromospheric eruptions apparently causes radio-echo disappearance through absorption in this region of high collisional frequency. The production of this high ionization is the necessary condition for the magnetic disturbance of the diurnal-variation type and its recognition is a definite step toward understanding of magnetic perturbations."

Further interesting investigations of the "new" physical force which binds together the protons and the neutrons of atomic nuclei confirm and extend the observations and measurements reported last year.

"This force," Dr. Fleming states, "has long been inferred to exist as a universal property of matter, ranking with gravitation and electromagnetic forces in its importance to the structure of the cosmos. Its direct observation and measurement last year, using the Department's high-voltage equipment, now strikingly confirmed by the new measurements, is an achievement of lasting importance. Other measurements in connection with these investigations, relating to neutron-intensities, appear separately important to biochemical, genetic, and cancer researches, and exemplify the wide significance and application of such fundamental studies. Precise measurements on the most familiar group of nuclear transmutations—those of lithium—demonstrate the existence of an unexpected four-body process, and give hope of a future experimental demonstration of the existence of the hypothetical particle called the neutrino, which has been assumed to exist because of certain crucial difficulties in the understanding of transmutation-processes involving electron (beta-ray) emission."

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A major development, which will be of great importance to the future of the Department's program, was the beginning of the construction of a long-needed high-voltage equipment of considerable size, with associated facilities—a project which has been given the name "Atomic-Physics Observatory." The large steel tank with its surrounding building and underground tunnels and vaults resembles an astronomical observatory in outward appearance. The designation "observatory" is not without justification in view of the smallness of the regions of space to the study of which the equipment is dedicated—regions whose remoteness from ordinary dimensions and conceptions of size suggest for their expression relations corresponding to astronomical magnitudes.

The new equipment will consist of a large electrostatic generator and vacuum-tube enclosed in a pear-shaped steel vessel 55 feet high and 37.5 feet in diameter at the upper end. Air in the vessel is to be compressed to 50 pounds per square inch for electrical insulation of the generator and tube, which are designed to operate under precise control at potentials exceeding 5,000,000 volts. An underground tunnel-maze and control-room surrounded on all sides by earth for shielding of operators and instruments against X-rays and neutrons has been provided. This new installation, crystallized in the design of this equipment three years ago, has been looked forward to for several years. It embodies, on a moderate but adequate scale, the numerous technical developments looking toward analytical and precise observations evolved by the Department's studies over many years on the application of high voltages to nuclear-physics problems.

## THE WORK OF MOUNT WILSON OBSERVATORY

The scope of solar investigations during the past year has expanded greatly because of the rapid increase in solar activity and the near approach to sun-spot maximum, which will not be reached, it is expected, before the end of 1937. This expanded solar program has included special investigations on bright chromospheric eruptions; on intensities and contours of lines in the solar spectrum at different distances from center of the solar disk; the wavelengths, intensities, and identifications of lines in the infrared solar spectrum; the photometry of sun-spots; the infrared spectrum of sun-spots; the motions of prominences; the ultraviolet spectrum of the sun; the possible identification of faint solar lines; the telluric lines in the spectra of high and low sun; the chromosphere and corona, observed at Canton Island during the total eclipse of June 8.

Methods have been developed for keeping the sun under nearly continuous observation for long periods leading to interesting conclusions as to the connection of solar eruptions with radio fade-outs and magnetic storms on the earth. Dr. R. S. Richardson, for example, has been studying the bright short-lived eruptions which often reach maximum brightness in a few minutes. He finds that their effectiveness in producing radio fade-outs depends primarily on their intensity rather than upon their position on the solar disk; that the bright material is at a high level in the solar atmosphere; that the eruptions are visible not only in hydrogen light but in that of calcium and some other metals; that they cover relatively small areas of the sun's surface; and that they are generally but not always near active sun-spot groups.



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At the invitation of Director Robert R. McMath, Dr. Edison Pettit spent the months of July and August at the McMath-Hulbert Observatory of the University of Michigan, studying prominence motions by the motion-picture method. Observations were made in collaboration with Mr. McMath on 43 days, and a total of 2000 feet of film was obtained. Effort was concentrated on prominences of the sun-spot and active types. The films were measured on a machine constructed at Mount Wilson. The frequency of exposures, generally of the order of 25 to 45 seconds, permitted detailed studies of prominence motions not hitherto available.

Sometimes complete loops appear, rising from and returning to the spot area like a fountain. The loops may rise to great heights, nearly reaching the eruptive stage before returning to the center of attraction. Eruptive prominences are probably extreme cases in which the trajectory becomes a tall, narrow loop, and the prominence fades out before completing its trajectory.

The chromosphere is in continual motion, rising and falling like surf on the coast line. Occasionally a mass will burst through the chromosphere, rise, and sink back. Such prominences have been called surges and, when abnormally bright, are the bright chromospheric eruptions associated with radio fade-outs. One of these observed on August 8, 1936, rose to a height of 80,000 km with a velocity of 240 km/sec; it was 50 per cent brighter than the chromosphere and coincided with a radio fade-out.

At the invitation of Dr. S. A. Mitchell and the National Geographic Society, the Observatory took part, with Dr. Theodore Dunham as its representative, in the eclipse expedition to Canton Island in the Pacific Ocean sponsored



by the National Geographic Society and the U. S. Navy. A spectrograph was set up and used, with a new very bright grating ruled by Dr. Harold D. Babcock, to photograph the spectrum of the corona on plates and the chromospheric spectrum, at closely spaced intervals, on motion-picture film. The eclipse was observed under ideal circumstances and, while it was not possible, under the conditions available, to operate the motion-picture spectrograph as planned, several flash spectra of good quality were obtained. The spectrum of the corona shows at least one line not previously recognized.

Dr. F. E. Wright, Chairman of the Committee on Study of the Surface Features of the Moon, continued his measurements of the percentage amount of plane polarization produced in light reflected and diffracted by terrestrial and lunar surface materials. On the basis of the data on polarization obtained on terrestrial materials, it is possible to separate them into groups and to compare their characteristics with those obtained for different areas on the moon. Visual measurements of plane polarization have been made on a large number of terrestrial substances; the results obtained are in accord with the conclusion drawn some years ago that the surface materials of the moon are of the nature of volcanic ashes and pumice high in silica content.

Study of the shapes and sizes of lunar surface features has been made on a series of photographs of the moon's surface by observation of the angle of grazing incidence of the sun's rays on a given slope. This study is of a preliminary character, preparatory to a more detailed study of a series of photographs to be taken with the 100-inch telescope throughout an entire lunation.

The important investigation by Dr. Alfred H. Joy of the spectra of Cepheid variables which has extended over 17 years and has included 190 stars north of declination  $-40^{\circ}$  has been brought to a conclusion and the results are nearly ready for publication. Only 25 of these stars had been observed previously with the spectrograph, but, with the aid of low dispersion, observations have now been carried to stars of the fourteenth photographic magnitude. More than 1000 spectrograms have been measured for radial velocity, the normal velocity and the range being determined for each star. Velocity-curves have been drawn for 106 stars.

Statistical studies of the data indicate, according to Dr. Adams, the Director, that, while the scatter is considerable, the correlation between period and velocity-range is well marked. The time of maximum velocity of approach occurs somewhat later than that of maximum light, and maximum velocity of recession falls after minimum light. The mean lag is about 7 per cent of the period, the general increase with length of period being well shown. The results will be used to determine the peculiar motions of these stars, their motions with respect to the sun, and the rotation of the galaxy.

Since 1924, more than 1000 spectrograms of early-type stars have been obtained by Dr. Paul W. Merrill and Dr. R. F. Sanford in an extensive investigation of absorption lines due to interstellar matter. Approximately 720 are of the region of the D lines of sodium in the spectra, and 300 are of the H and K lines of calcium. Of 404 objects observed, 147 are fainter than apparent magnitude 7.0. All the plates have now been measured and reduced and the results are ready for publication.

Study of the distance-intensity relationship in 23 areas in the sky has revealed no great regional differences. The form of the relationship out to a distance of 2000 parsecs has been determined from the D lines. Although galactic rotation seems to be of minor influence in producing the observed intensities of the D lines, its effect is plainly marked in the observed displacements of lines in stars of different longitudes. A study of the relative intensities of D1 and D2 leads to the conclusion that the properties of sodium cannot be identical at all points in interstellar space, and, when considered in conjunction with the effect of galactic rotation, suggests the presence of discrete clouds of sodium gas which are several hundred parsecs across and have appreciable random velocities. An upper limit of  $40,000^\circ$  is found for the temperature of the interstellar sodium gas and a density of about  $10^{-31}$  gr/cc. The structure and the mean wave-lengths of the unknown diffuse interstellar lines in the yellow and red have also been studied in the course of this investigation.

The use of high-speed red-sensitive plates, by Dr. Walter Baade and Dr. Rudolf Minkowski, in the photography of regions affected by obscuring matter has led to most interesting results. Spectro-photometric measures of early-type stars in the central part of the Orion Nebula indicate selective absorption by particles with diameters of the order of  $150 \text{ m}\mu$ . In the Milky Way heavily obscured globular clusters like NGC 6553, which on blue-sensitive plates show but few stars, are found to be extremely rich in stars on the red-sensitive emulsions. In several cases this high color excess is shared by the surrounding star fields, a result which suggests that much of the effect must be due to relatively nearby clouds.

Test plates in the region of the galactic center indicate that strong reddening affects nearly all of the partially obscured Milky Way star clouds. A program is now under way to survey the region with the greatest available penetrating power both in the red and, if possible, in the infrared.

The distribution of nebulae in depth has been investigated by Dr. Edwin Hubble, using four Mount Wilson surveys and a fifth made by Dr. Mayall at Mount Hamilton. The surveys, reduced to a homogeneous system, represent about 100,000 nebulae and extend to about the effective limits of the 100-inch reflector.

The data are closely represented by uniform, large-scale distribution, provided the apparent magnitudes are corrected by quantities which are linear functions of distance. These corrections are attributed solely to the dimming effects of red shifts in order to avoid a symmetrically increasing density outward.

The interpretation of the results involves cosmological theory. The law of distribution and the law of red shifts furnish a provisional, empirical test of the theory of expanding universes which obey the relativistic laws of gravitation. The data are consistent with only one model—a monotonic universe of the first kind—which is closed, small, and quite young.

On the other hand, if red shifts are not velocity shifts, but are due to some unknown cause which does not involve motion, the observable region is thoroughly homogeneous and is too small a sample to indicate the nature of the universe as a whole.

The relationship of the Observatory to the visiting public has been a subject to which much study has been given

during past years. The completion of the new auditorium and exhibits building has made it possible to present the work of the Observatory in a much more nearly adequate and satisfactory way than heretofore and aids greatly in its effective utilization by the public.

#### THE PLANT BIOLOGY PROGRAM

Dr. H. A. Spoehr, Chairman of the Division of Plant Biology, submits the observation that the gap between the discovery of facts and their application is narrowing rapidly. His statement which follows is of much interest.

“Agencies which make use of scientific facts and principles have highly trained experts who know how and where to obtain the special information needed for their particular purposes. The dissemination of information for such purposes and the cooperation with other agencies can under certain circumstances be a source of intensified effort and stimulus for investigators in an institution such as ours.

“There is still an enormous and promising field in the chemistry of natural products, particularly those of plant origin. This has a bearing on the development of our knowledge of the factors and influences determining plant growth, the elements in plant crops of importance to human nutrition, and also on the vast field of raw materials of value to industry. The products manufactured by the plant through photosynthesis constitute an inexhaustible supply of valuable and cheap raw materials from which a multiplicity of substances of great value to industry can be synthesized by chemical means. The plant manufactures predominantly materials consisting of units of five and six carbon atoms, exemplified in the



pentose and hexose sugars, which are variously combined to make up starch, cellulose, pectins, and the like, from which an almost inconceivably large number of products are elaborated by the plant itself and which can serve as raw material for a host of artificially synthesized products.

“But a few years ago the pigments of plants, as a subject for scientific investigation, had chiefly only academic interest. With the development of our knowledge of the chemical structure and properties of these substances came an understanding of the important function of some of them in animal nutrition and metabolism. Fundamental researches on these carotenoid pigments have made possible significant advances in the science of nutrition, and have found application not only to human nutrition but also to many branches of agriculture, such as dairying, animal husbandry, and poultry raising.”

There has recently been a strong growth of public interest in the arid parts of the United States on account of the comprehensive studies of land use, soil conservation, and range restoration which have been undertaken by various agencies of the federal government. The Desert Laboratory has met increasing demands for basic physical, climatological, and botanical data of immediate value to governmental and private undertakings concerned with the use of arid regions. Knowledge which has highly practical value today has, in many cases, grown from work which was begun many years ago because of its manifest scientific importance. This is particularly true of the study of changes in vegetation over long periods and of the investigation of the distinctive features in the life histories of some of the very dissimilar plant types which meet arid conditions successfully.



Also originating from the work of the Desert Laboratory, a wealth of practical information has resulted from the extended observations, now covering almost half a century, which have been made by Mr. Godfrey Sykes, on the physiographic history of the delta region of the Colorado River. The rhythm of flow of this stream has recently been changed fundamentally by the construction of the Boulder Dam. The long investigation constitutes a most valuable record of the dynamics of the stream and the manner of deposition of detrital material within the deltaic area, which comprises a basin of over three thousand square miles and contains one of the most productive irrigated agricultural areas of the world. This life work, which includes a study of the early human history of the region, is being brought to publication, two volumes having already appeared.

For many years one of the major subjects studied by Dr. F. E. Clements has been the ecology of the Great Plains and its bearing on the agriculture and human population of this immense area. The development through these studies of a comprehensive viewpoint on this subject has been of assistance in correcting a number of popular misconceptions regarding the future of this region. It is argued that if the past can be taken as a guide, the recent drought period in this area was not the first of such events and it will not be the last, and, moreover, that the dust of storms which accompany the drought is often due to disturbances wrought by man. Dr. Clements considers that a misconception resides in the assumption that short-grass is the natural vegetation of the plains; that short-grass is rather a consequence of overgrazing. Evidence has been accumulated to show that the true climatic grass-

land is a mixture of short grasses with such taller ones as wheat and spear grass, which indicate a climate suitable to wheat-growing in the main.

With the discomfort and tragedy of dust storms before the nation, it was inevitable that proposals to regrass all or most of the crop lands of the Great Plains should meet with practically universal approval. However, it is pointed out that this failed to take into account the slowness of natural recovery in abandoned fields, which often require thirty to forty years, and the difficulty and cost of artificial regeneration by seeding and planting. Evidence has also been presented in support of the contention that the Great Plains are a valuable reservoir of soil fertility, from which satisfactory yields of wheat can be secured through large-scale, progressive methods. As a result of these prolonged climatological and ecological investigations it is concluded that long-range forecasting of rainfall and drought must come to play an important part in planning crops and insuring production. Even more helpful at present is believed to be the use of measurement of soil moisture throughout the year to determine the probable success of winter wheat or the desirability, with deficient rains, of plowing under in the spring in order to save the moisture for the following year.

In experimental taxonomy, the nature of the barriers that limit natural species and subdivisions of species have been further investigated. One large second-generation hybrid population of tarweeds demonstrated that the original parents, which were regarded as different subspecies of the same species, actually represented transitional stages between subspecies and full-fledged species.

Here, experimental evidence showed that the evolutionary differentiation from a subspecies to a species may be a gradual and cumulative process. In contrast is the rare situation in which species may arise essentially *de novo* as the result of hybridization between preexisting species. Supporting evidence to this effect was contributed from the Plant Biology Laboratory a few years ago, and evidence is now accumulating toward the establishment of two additional cases of this sort. Conclusive evidence that subspecies of a species may differ in chromosome number has been given by a second-generation hybrid population of 2500 individuals. So far as we know, this is the first case in which the difference in chromosome number, through incompatibilities, has not created barriers of at least specific importance.

In an attempt to bring the cyclograph into more general use, it was reconstructed out of metal in 1936 and so designed as to include various convenient rearrangements of the parts. The new cyclograph was exhibited in Washington, D. C., by Dr. A. E. Douglass, who developed this instrument, in a third cycle conference, held April 23-25, which was attended by a group of investigators concerned with cycle analysis. The group included astronomers interested in the analysis of variable-star periods and in cycles of solar activity; members of the Department of Terrestrial Magnetism of the Carnegie Institution who are doing a very important work on reception, measurement, and analysis of solar radiation of different kinds, as well as on cosmic rays; astronomers and meteorologists interested in the analysis of solar and terrestrial cycles; economic meteorologists interested in the possible influence of the sun on weather and crops; and students of business

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activity. In these various groups there was general recognition of the utility and great speed of the cyclograph in preliminary surveys of data.

This conference brought out the fact that it is difficult for one who is accustomed to periods which are permanent and exact, to realize that climatic and solar cycles are not permanent or exact and yet have important characters that can readily be investigated by the cyclograph. It is in just such cases that this instrument shows its unique power to resolve cyclic repetitions. It is hoped that a clarification of the term "cycle" in conjunction with more general use of the cyclograph will facilitate further investigation into the complexities of climatic and solar variations.

## RESEARCHES IN ANIMAL BIOLOGY

The process of discovery is so intricate that doubt is thrown upon the wisdom of requiring investigators or groups of investigators to hold too rigidly to direct attack upon specific objectives. Any procedure in research that savors of regimenting science is usually disappointing in its results. On the contrary, it is not an uncommon happening that the indirect and unexpected developments of an investigation, the by-products so to speak, are of commanding significance. This is well illustrated in certain investigations conducted by the Departments of Embryology and of Genetics which are described by Dr. George L. Streeter, the Chairman of the Division of Animal Biology:

"It is, therefore, of interest to point out that in the Department of Embryology, where studies are being made in the general field of the structure and physiology of the living cell, it has come about that the tumor cell has been

the object of considerable study; and it was chosen because it offers certain advantages for the study of cell activities. Observations have been made, however, which are fundamental to the cancer problem. For example, crucial evidence has been obtained indicating that the malignant cell is a permanently altered one that breeds true. After such malignant cells are once established they multiply independently of the agent or environment which produced them and their growth can be continued indefinitely by transplantation from animal to animal and by means of tissue cultures. Furthermore, in the same laboratory it has been found during the past year that the presence of growing malignant tissue results in an increase in one of the varieties of white blood cells both in the peripheral blood and in the blood-forming organs. This phenomenon is characteristic for certain tumors and such tumors are transplantable into mice of the same strain. The host's resistance, however, can be altered as well as the strain specificity of the tumor itself.

“At the same time a group of workers in the Department of Genetics has been studying the occurrence, transmissibility, and pathology of leukemia as it is found in mice. This is not cancer, but it is a malignant growth and, in a way, a tumor. Leukemia differs from cancer in that the leukemic cells in their various stages of development are cytologically normal, but they differ from the normal in their rate of differentiation. Malignant lymphocytes differentiate more slowly than normal ones. This results in the accumulation of large numbers of the more primitive cells, although a certain number of fully mature cells are constantly being formed. The rate of differentiation appears to be related to the degree of virulence.



The slower the development, the more virulent is the population, and the larger is the proportion of primitive cells and the more rapid is their increase in number. As a whole the population is leukemic, but as individual cells they appear to be normal in all respects except in their rate of differentiation.

“Other studies on mouse leukemia are being made with a view to determining the operation of genetic variables and specificities. The conditions have been determined by which resistance to leukemia can be set up by repeated sublethal doses of leukemic cells themselves, also resistance to transplanted leukemic cells has been induced by treatment of the host with embryonic tissue. It has thus been possible by varying the experiments to test the relative values of the many factors involved, namely, genetic constitution of the host, modified constitution of the host, intrinsic properties of the leukemic cells, modified virulence of the leukemic cells following repeated transplantation, and genetic constitution of the embryos that supply the embryonic tissue. It is quite evident that these breeding and inoculation experiments at the Department of Genetics and the tissue-culture and tumor-transplantation experiments in the Department of Embryology are producing some of the fundamental facts upon which an understanding of the nature of cancer must eventually rest, even though these facts are but a by-product of what a medical man would probably designate as pure research, meaning research for research’s sake.

“The studies which have been mentioned have been made by different groups of workers primarily independent of each other. They concern related problems but are approached from different angles and so are complemen-



tary. It is obvious that intercommunication between the groups should be frequent and full, in so far as this can be brought about without infringement upon the backgrounds and approaches of the respective groups. Such an intergroup awareness is facilitated by our administrative organization as a Division, and the distance separating Baltimore from Cold Spring Harbor is not allowed to be a barrier."

So, also, in the field of endocrinology, items will be found in the reports of the Department of Embryology, the Nutrition Laboratory, and the Department of Genetics which are similarly impressive in showing the value of diverse approaches. In each case there were special circumstances that suggested the investigations and determined their character. Just as tissue cultures of mouse tumors, in the investigations already referred to, are a basic contribution to cancer research, so the material secreted by the crop glands of pigeons is providing a means of solving some of the most interesting problems of the ductless glands. Indeed, it is through this agent that doubt has been thrown upon the separateness or singleness of a "growth" hormone in the pituitary gland.

Another very complicated field in which attack from many vantage points is called for is that of the physical expression of the gene and its bearing on the structure of chromosomes.

In the Department of Embryology the fly *Sciara* has been the material chosen; in the Department of Genetics the material employed has been *Drosophila*. *Sciara* possesses the advantage of having very large salivary chromosomes that are especially suitable for cytological study, but it has the disadvantage of not being so thoroughly

known genetically as *Drosophila*. In commenting upon these approaches to study of chromosomal structure Dr. Streeter states:

“It is clear that genetic methods alone are too crude for the final analysis of many genetic changes. To determine what actually happens when a change in a chromosome occurs, we must resort to its detailed cytology. There must be a close coordination of genetic and cytological studies if we are to understand the nature of genetic changes, and this we are attaining by the maintenance of different research groups.

“The fact that each ‘giant chromosome’ of *Sciara* is really a pair of homologous chromosomes fused side by side has made it possible to analyze small differences in these components, and it is hoped that in this way the ultimate unit may be disclosed. There is considerable evidence that the idea of a multiple threadlike structure (chromonemata), which had been postulated for the chromosome, must be revised. If the giant chromosome were simply a cable of component fused chromosomes, its size would require a number that is greater than can be accounted for. From the genetic side, the group working with *Drosophila* have made many experiments with refined methods of radiation. From their observations on the effect of soft rays, the dosage-effect curve for chromosome breaks, and the fact that the injury is influenced by biological factors, it becomes probable that in radiation experiments the genes are affected indirectly through changes produced in their environment.

“A study has also been started on the effect of neutrons. This was made possible through the cooperation of the Department of Terrestrial Magnetism. In the prelimi-

nary tests for the frequency of X-chromosomal lethals it was found that hereditary changes can be produced in this way and that the effectiveness of the neutron treatment increases with the dosage applied. From the physical standpoint it is expected that neutrons will produce changes that are different from those caused by X-rays, and some clue may thus be obtained as to the mechanism by which such changes are produced."

In referring to the great work in nutrition upon which he has been engaged, Dr. Francis G. Benedict writes as follows in his annual report:

"It has been necessary to spend a large amount of time, many of us feel an undue amount of time, in the development of the peculiar techniques required for our general lines of attack. Fortunately we are now able to leave these elaborate techniques and present extremely simple forms that are rapidly being introduced into other laboratories.

"A study of the physiology and psychology of man by reference to similar studies on animals has been a most fruitful field of research for years. The abnormal in man is often normal in the animal and an understanding of the true nature of the normal process is imperatively needed in interpreting the abnormal manifestations. Some of these problems are so salient that the writer feels justified in stressing their importance along with the high degree of probably successful attack by methods developed in the Nutrition Laboratory. With no group of animals have there been any greater possibilities of results of specific value to man than with domestic livestock. Comprehensive studies on such animals have been pursued, in collaboration with Professor E. G. Ritzman, at the University of New Hampshire, where our technical methods of

attack are particularly needed on a considerable number of pressing problems in the physiology and in the economic life of ruminants and horses in their associations with and relations to man. Active preparations are going on for furthering this research, and the certainty of securing valuable and important results makes such a research thoroughly justifiable.

“With humans and with animals one of the larger problems necessitating direct calorimetric measurements, that is, the establishment of the caloric value of oxygen and carbon dioxide at respiratory quotients not only between 0.70 and 1.00 but considerably above 1.00, has been so far solved that we believe there is little, if anything, remaining to be gained in most investigations by further use of direct calorimetry. In problems dealing with gaseous metabolism, however, the situation is quite different. The studies in comparative physiology have brought out strikingly the physiological, the pathological, and undoubtedly the therapeutic importance of knowing the amount and variation of the carbohydrate reserve in the body, the influence of depletion of this reserve, and with humans the conditions that affect its storage, its amount, the rate at which it is drawn upon, and the rapidity with which it is refilled. Although little has been done on this basic problem, fortunately the technique of today permits perhaps for the first time precise measurements of this reserve.”

Likewise in the field of nutrition extremely interesting work on relation of food to length of life has been carried on by Dr. H. C. Sherman, of Columbia University, under support from the Institution by aid of grants from the Carnegie Corporation of New York. Some of the

results of this work have been described by Dr. Sherman as follows:

“The experiments described in previous reports as designed to ascertain what chemical factors were concerned in the nutritional improvement of an already adequate diet which we had reported, have now been completed, and a paper embodying a report of the findings has been prepared for journal publication. Increased intakes of calcium, of vitamin A, and of the riboflavin previously called vitamin G, all appear to have contributed to the enhancement of vitality or positive health and to the increased length of life which had been shown to result from an increase in the proportion of milk in an experimental dietary which was already adequate in the accepted sense that it supports normal growth, health, reproduction, and lactation, generation after generation. (Families of laboratory rats are still thriving in the forty-second generation upon this original adequate but not optimal dietary.) From the viewpoint of the state of knowledge when these experiments were begun four years ago, it was deemed more scientific to supply the dietary enrichments of vitamins A and G (riboflavin) accompanied by their natural concomitants rather than in any such artificial form as would, in addition to questions of chemical purity, involve an assumption that no other known or unknown substance could have been a significant factor in the preceding experiments . . .

“These later experimental findings thus bear out the suggestion of our previous reports that there may or may not be a demonstrable relation between the nutritional acceleration of growth and the subsequent length of life, according to the nature of the original diet and of the



dietary factor which is varied in the particular case. Of chief interest in its bearing upon human affairs is our repeated finding that, starting with a food supply analogous to those upon which most people actually subsist, it is possible to expedite growth and development, improve the average of adult vitality, and extend the life cycle, all in the same individuals, by such adjustments of the relative proportions of staple articles of food as to enrich the dietary as a whole in certain of its chemical factors."

The section of the Department of Genetics devoted to studies in eugenics, in addition to continuance of basic studies, has been collaborating with the state of Connecticut in a survey of the human resources of that commonwealth. Dr. Harry H. Laughlin, in charge of the Eugenics Record Office of the Institution, was appointed director of this survey. In making this survey the Commission was particularly instructed by the Governor to investigate the source, the apparently increasing supply, and the racial, moral, and economic costs of the human inadequates who finally, either directly or indirectly, become economic charges regardless of cause or blame.

During the past year the Tortugas Laboratory suffered the loss of its Executive Officer, Dr. William H. Longley, who died in Baltimore on March 10, 1937, following an illness of several months' duration. Dr. Longley had been associated with the work of the Tortugas Laboratory since 1910, and since 1922, as Executive Officer he has served as the successor of Dr. Alfred G. Mayor. The readers of the Year Books since that time will not need to be told that he filled that position conscientiously and in an effective manner. Through him the Mayor traditions were carried on and under his leadership the Laboratory was



visited each year by competent investigators from this country and abroad, who found there an atmosphere of genuine and enthusiastic devotion to research and a pervading web of cordial helpfulness which bound the group together in their progress toward a common goal.

Dr. Longley was succeeded as executive officer by Dr. David H. Tennent, by whom the Laboratory was directed in the 1937 season. During the twelve weeks of its operation it was visited for longer or shorter periods by seventeen investigators, two of whom were from England and one from Belgium. The investigations carried on during the summer include: physiology of *Valonia*; influence of carbon dioxide in the effect of light on the electromotive force of *Valonia*; photodynamic effects of vital dyes; implantation of embryonic fish tissue; oil-cytoplasm interfacial tensions; rôle of mangrove vegetation in land building; studies on coral reefs; swarming of the Atlantic palolo; experiments on ascidians; the ciliates of sea urchins; function of fin movements in equilibrium of fish; development of the dorsal spine in the sting ray; regeneration in holothurians; development of chela in Crustacea under gamma radiation; and tumors of fishes.

#### HISTORICAL RESEARCH

The year's investigations have yielded an unusual amount of valuable material. Of outstanding archaeological importance were data upon ball courts and upon the great Hieroglyphic Stairway gathered by Mr. Strómsvik and Dr. Morley at Copan; a remarkable fresco and hieroglyphic inscription found by Mr. A. L. Smith at Uaxactun; and the excavations near Guatemala City, in an area hitherto little known, conducted by Dr. A. V.

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Kidder, Chairman of the Division, furnishing a large collection of pottery, jades, and other mortuary objects. Work upon the living Maya under direction of Dr. Redfield resulted in the obtaining, by Sr. Villa, of much knowledge regarding the fast-fading native culture of the Indians of eastern Yucatan. The historical research was rewarded by discovery of unsuspected documentary riches in the archives of Guatemala.

Referring to recent work in archæology, Dr. Kidder describes the program as follows:

“After twelve seasons of intensive investigation, the Division’s activities at Uaxactun were brought to a close on May 15, 1937, and the camp and permanent equipment were turned over to the Government of Guatemala. Originally selected by Dr. Morley for excavation because, on the basis of its dated monuments, it was both the oldest and the longest inhabited of Old Empire Maya cities, Uaxactun has paid consistently rich scientific dividends. Work there is now being terminated not because the site is even approaching exhaustion, but in order to allow Mr. Smith and his associates to bring up to date their studies of, and publications upon, the large collections and the abundant data already recovered. And it seems probable that when these tasks have been accomplished problems will have been formulated which will call for comparative research at other sites. . . .

“The third season of cooperative work at Copan, by the Government of Honduras and Carnegie Institution of Washington, opened December 1, 1936, to take advantage of the full six months of dry winter weather. Activities of the year were: further attempts to protect the ruins from destruction by the Copan River; study and repair

of the Hieroglyphic Stairway; and completion of study and repair of Temple 22. As in former years, the Honduranian Government has defrayed all costs of labor and of the transportation of supplies. . . .

“In the struggle with the river, the dam which had been built in 1936 and later washed out by the summer floods was replaced by a longer dam reenforced by several hundred piles, and the diversion canal was widened and deepened. Signs of a flank attack by the rising waters of early summer were becoming evident when Mr. Strómsvik left Copan in June, and it is possible that complete diversion of the river may never be feasible. If so, protection by riprapping will have to be afforded the base of the Acropolis. It is imperative that this important structure be saved.

“Repair of the magnificent Hieroglyphic Stairway was begun. Dr. Morley, who was at Copan for a month in the late winter studying new epigraphic material, and assembling and arranging the fallen sections of the stairway preparatory to their replacement, reports that about sixty-two steps constituted the original flight. Only the bottom fifteen were in situ. Fifteen others, however, had slid downward en bloc. These, excavated in the 1890’s by the Peabody Museum of Harvard University and laid out in the plaza in their proper order, were replaced during the past season in the position which it is almost certain they had formerly occupied. . . .

“In connection with reconstruction of the Hieroglyphic Stairway, the summit of Mound 26, up which the stairway led, was investigated in order to find the level of the temple platform as one check on the number of steps in the stairway. No indications of a building were evident until removal of surface débris revealed large, scattered frag-

ments of a very thick, hard floor. By fitting these together, like sherds of pottery, most of the outline of a chamber was reconstructed. Its limits were clearly indicated by the turned-up edges of the flooring where it had abutted the walls, and the doorway was located by pieces which projected beyond the line of the front wall. Forty-four beautifully carved stones were found. These had formed part of a four-course frieze of full-figure glyphs, probably across the medial wall, two courses apparently in the wall and two in the vault. Two stones of the lower course had cord-holders, indicating that the band had been carried on wooden beams over an interior doorway. Some seventy similar stones from the slopes of Mound 26 are now in Peabody Museum and in Tegucigalpa. It is probable that they are part of the same frieze and that the assemblage can be completed. If so, it will constitute the longest inscription now known in the very rare full-figure hieroglyphs. . . .

“Mr. Karl Ruppert spent six months at Chichen Itza gathering data for an evaluation of Nahua influence upon the architecture of that city, and for a report on such structures as have, wholly or in part, been excavated and for which there is no published record. A survey and analysis of the Nahua structures presupposes a knowledge of the Maya buildings at the site. This survey is to be purely local and such facts as may be determined will apply only to Chichen Itza and here, of course, will be true only as far as present excavations have been conducted and surface examinations extended. Certain architectural features such as serpent columns have come to be identified as definitely Nahua; thus buildings in which these are utilized in key constructions must be considered

as of the late period. Late concepts appear in early structures only where they have been added as roof ornaments or other superficial decorations, never as fundamental elements of construction.

“The survey has included the examinations of eight ball courts. Seven, in which stone rings have not been found, have benches one-third or less the length of the largest court. All are apparently of the late period and show great differences in slope of face and top of bench. The main walls, however, seem to rise vertically. Because of the extreme variation of the courts, it is evident that the game could not have been standardized; and the possibility of its having been played in the single enormously large court may, in Mr. Ruppert’s opinion, perhaps even be questioned.

“The plans of structures in the two periods show little in common. The two-chambered temple resting on a lofty pyramid and now encased within the Castillo is, if correctly interpreted, the only example of such a structure in Maya times. Buildings of the palace type are not associated with the Nahua. The shrine room, which is not represented here in the Maya period but is found in their cities to the south, was developed and elaborated by the late people of Chichen Itza. Arrangements of colonnades of one to four vaults in depth, colonnades and temples, and cloisters appear that do not have counterparts in early structures.

“Carved stone was the medium used for building ornamentation during both periods, and practically all motifs are carried from early to late times. Façades in both periods, except for two- and three-member moldings, may be plain. If ornamented, those of the Maya showed a



tendency toward over-all decoration, while the Nahua more consistently simplified the treatment by the use of alternate plain and sculptured panels. Realistic bas-relief was not attempted by the Maya.

"Differences are noted in the manner of cutting, dressing, and laying stones, and in late times stones of the vault were highly specialized. The floor level of the inner chamber is placed a step up from that of the outer chamber—a common Maya feature which is not seen in unquestioned Nahua structures. Numerous minor but evidently none the less significant differences in construction, developed or brought in by the Nahua, become apparent as the material is analyzed. . . .

"Kaminaljuyu, a great aggregation of mounds in the southwestern outskirts of Guatemala City, has long been known to archæologists and has long been believed important because Gamio's excavations of 1925 had revealed the presence there of a presumably early culture; because of Lothrop's identification of sculptures indicating influence from the Maya Old Empire; and because, being situated athwart probable highland routes of migration and commerce, it might be expected to yield trade objects valuable for determining cultural and chronological relations between various Middle American civilizations." The Institution began work here in 1935 under the immediate direction of Dr. Kidder, with excavations to check Gamio's findings. Much ceramic material from the early period was recovered. In 1936 a mound on Finca La Esperanza was partially excavated; it was completed during the past season and the frontal terrace of a second mound was investigated.



“Mound I proved to consist of eight structures, built one over the other. The two innermost were rectangular, vertical-walled platforms, the first of masonry, the second of adobe; the next six were truncated pyramids, the first four of adobe, the last two of water-rounded tufas laid in adobe. The total height of the complex was about 6 meters. . . .

“Of Mound II only the frontal platforms were excavated. Like those of Mount I, they covered tombs, two of which could be assigned to the two major building stages of the platform; the third was intrusive. . . .

“Interments and accretions to the mounds were apparently correlated, and definite connection between certain tombs and certain structures could be determined. Relative uniformity of funerary practice and close similarity between pottery from all graves indicate a short timespan for the entire series. The pottery evidences trade relations with northern Peten during the Tzacol period (middle to late Old Empire) and with Teotihuacan, Mexico. . . .”

Dr. Kidder reports that at Kaminaljuyu three ceramic phases have so far been identified: Miraflores, early, possibly akin to the Mexican “Archaic”; Esperanza, the phase of the mounds and tombs, contemporaneous with the Maya Old Empire; Pamplona, crude, late, as yet unrelatable to any other group. Surface sherds from elsewhere on the site suggest presence of additional phases, and raise hope that it may eventually be possible to trace a long, continuous local evolution whose stages can be fitted into the larger scheme of Middle American cultural development.

In discussing the new technique in study of ceramics Dr. Kidder states:

“Of all archæological materials, pottery is the most useful for tracing the development and spread of cultures, and for measuring the strength and identifying the source of external cultural influences. But its value for such purposes depends upon the certainty with which ceramic types can be recognized and defined, and upon the accuracy and uniformity of their description. Until very recently, however, pottery has been classified almost solely on the basis of its external characteristics—vessel form, color, decoration—features so subtly variable that their recording in terms sufficiently objective to be of service to other students is extremely difficult. Attempts have been made to use the more definite and tangible evidence offered by clays, tempering materials, and pigments; but success has hitherto been meager, because no archæologist has had the highly specialized knowledge required for certain identification of the various ceramic ingredients.

“When, therefore, Miss Shepard, a trained petrographer, began the study of ceramic technology, she entered a practically virgin field. Her work on ancient Pueblo pottery quickly demonstrated its value in permitting more accurate and more objective description of wares. She has also often been able to recognize, in pottery, mineral inclusions not found in local deposits and, by identifying their source, has not only proved the vessels in question to be trade pieces, but has in many cases been able to determine their place of origin. This is obviously of the greatest importance to the archæologist.

“Miss Shepard, through cooperation of the Laboratory of Anthropology at Santa Fe, has for several years taken part in the Institution’s studies of Southwestern and Maya pottery. On January 1, 1936, she joined the Divi-

sion staff on temporary appointment. She has continued her research upon the collections of E. H. Morris from the La Plata region of northwestern New Mexico, and upon those of J. E. Thompson from British Honduras. During the past winter, she spent six weeks in Guatemala studying, with R. E. Smith, the wares of Uaxactun. An unexpected result of Miss Shepard's Maya work has been the discovery that a large percentage of the pottery from British Honduras, from Uaxactun, and even from northern Yucatan contains tuff temper, although no deposits of this material are presumably to be found within long distances of the sites producing the vessels. The pottery nevertheless appears to be of local manufacture. This raises problems of the extent and direction of aboriginal trade in raw materials, whose solution will throw much light upon prehistoric conditions in the Maya area."

As part of a research on the origin of maize and the distribution of relatives of maize, Messrs. Collins and Kempton made an expedition in October 1936, through the region of Mexico where the states of Chihuahua, Durango, and Sinaloa meet. This expedition was undertaken to establish the identity of a maize-like grass discovered near the town of Nobogame, Chihuahua, in 1895 by Lumholtz. To quote further from Dr. Kidder's report:

"At Cerro Prieto and at Nobogame, both approximately 7000 feet in elevation, the expedition found the grass described by Lumholtz. It proved to be teosinte (*Euchlana mexicana*), the nearest known relative of maize. There was no evidence, however, that the plant was utilized in the manner reported by Lumholtz. The Indians make no attempt to eradicate it from cornfields. Neither do they use the plants for forage, despite the fact that mine

pack trains cause such a demand for forage that most of the common cornfield weeds are husbanded for this purpose. . . .

“An understanding of how ancient populations met their subsistence requirements is essential for the reconstruction and evaluation of their civilizations. Accordingly, with the object of learning as much as possible about the agriculture of the Indians now resident in the region of Maya culture Mr. Stadelman has been stationed in the highlands of Guatemala since early January.

“In choosing the site for this investigation consideration was given to the racial composition of the population, to its relative freedom from European influence, its independence of an industrial outlet, and, since aboriginal agriculture in the Americas was primarily corn-growing, to the importance of this crop in their present economy. These major considerations and a host of minor ones led to the selection of Todos Santos, an Indian village in the Department of Huehuetenango in northwestern Guatemala, as the base from which observations would be made. . . .

“The study indicates that in the region of Todos Santos an Indian family of two adults and three children can obtain their subsistence requirements from the product of four acres with a labor expenditure of approximately 150 man-days. Evidence has been obtained that an effort is made to combat erosion on the steep mountainside farms, and the practice of fertilizing the soil with animal manure has been adopted by some Indians.

“The initiation of this investigation at this time proved fortunate, as the adoption by the Guatemalan Government of the work-book system, whereby every able-bodied adult male must prove employment for 150 days each year, or

work out the difference on the public highways, will tend to standardize the time spent on the farms at this figure."

Dr. Kidder refers to stage of advance of other projects leading to publication as follows:

"The eighth and last volume of Dr. Edmund C. Burnett's *Letters of members of the Continental Congress* was published in September 1936. This book completes a series inaugurated in 1921, and containing a total of 6125 letters, which, arranged chronologically, throw light upon the transactions of the Continental Congress throughout the entire period of its existence (1774-1789), during which time it sat with closed doors. The last volume includes a supplement of 30 letters from the years 1783-1784. Dr. Burnett is at present preparing a general or interpretative volume on the Continental Congress. In November 1936 he read a paper, 'Southern statesmen and the Confederation,' before the Southern Historical Association at Nashville, in the main a product of the studies for the proposed volume.

"The series entitled *European treaties bearing on the history of the United States and its dependencies*, the first volume of which appeared in 1917, was finished with the publication of the fourth volume in June 1937. For all the treaties in volumes I and II and for most of those in volume III the editor, the late Miss Frances G. Davenport, wrote introductions which made an approach to a consecutive history of European diplomacy respecting America down to 1713. Each treaty in the first three volumes is preceded by an extensive bibliography. Miss Davenport's death prevented the completion of the work on the last six treaties in volume III. These, as well as the



documents in volume IV, were supervised by the late Dr. J. Franklin Jameson. The documents for volume IV were edited by Dr. Charles O. Paullin, now retired from this Division.

"The series comprising *Judicial cases concerning American slavery and the Negro* was likewise completed with the publication of the fifth volume in July 1937. These cases, illustrating the history of the Negro and of American slavery as an actual working institution, as well as presenting aspects of American law and its development from the earliest time to 1875, were edited by the late Mrs. Helen Tunnicliff Catterall. Her death left unfinished some material for volumes IV and V, which were completed by Dr. James J. Hayden, a member of the faculty of the Catholic University Law School and of the District of Columbia and Maryland bars. . . .

"The fourth volume of Dr. Leo F. Stock's *Proceedings and debates of the British Parliaments respecting North America* will be published in November 1937. This series, planned to contain all available contemporary records, in print or manuscript, of parliamentary proceedings in England, Scotland, and Ireland concerning North America, begins with the year 1542 and will end with the acknowledgment of American independence in 1783. The fourth volume, now in press, carries the records down to 1739. . . ."

The preparation of volume III of the *Introduction to the History of Science*, by Dr. George Sarton, dealing with science and learning in the fourteenth century, has advanced considerably during the past year. It is hoped that the Latin and European part will be completed before the end of 1937. The very important Jewish part is already completed. When the Latin part is ready, it will



then suffice to revise the Byzantine, Arabic, and other oriental notes. The Chinese and Japanese notes will cause special problems, as it has been difficult to find a collaborator able and willing to revise them. All the notes not only for the fourteenth century but also for the fifteenth century have been ready for many years, but they are being gradually rewritten on a larger scale, all facts being investigated more fully than could be done the first time. The above remarks refer only to the analytical stage of the work. According to Dr. Sarton's method, no attempt at synthesis will be made until after the analysis of materials has been perfected in every possible way.

During the year steady progress has been made by Dr. Heidel in his research on early Greek philosophical and scientific thought. About one-half of the text is now typed, and the remainder is considerably advanced toward completion. Certain minor questions in the general field have been discussed in reviews of several important books that treat of related subjects; and the fundamental questions relating to the history and development of Greek geography have been considered at length in his book, *The frame of the ancient Greek maps with a discussion of the discovery of the sphericity of the earth*, published in June 1937 by the American Geographical Society as No. 20 in its Research Series. It is believed that in part I, for the first time, the principles are disclosed on which the Greeks constructed their general maps before the earth was conceived as a sphere. In part II, Dr. Heidel has attempted to determine as definitely as possible the date of this epoch-making discovery, and to show how the frame of the maps constructed on the assumption that the earth was a circular disk was adapted to the new conception of the earth.

**THE SAINT AUGUSTINE RESEARCH PROJECT**

If, as is commonly assumed, history of the United States has large importance in studies on the advance of civilization, it is essential that we know the story of this country in terms both of our present objectives and of factors which have had influence in origin of the nation.

Recognizing the importance of keeping in view certain critical problems relating to features involved in early history of America and their influence upon present and future questions, attention has been given to phases of history which still require investigation. Influence of the Spanish-American empire which developed south of the United States is expressed in many ways on the southern and southwestern borders of the country, and many of these historical questions have been made the subject of careful study. Other aspects of the questions still remain to be investigated and interpreted, and yet other problems are just now emerging in the course of continuing search for important materials. In the large field for research in the Southwest and on the Pacific Coast much of great historical interest and value has been developed. Other studies of significance have been carried out in the South Atlantic region, and especially in Florida.

Having in view the possibility of further research on the Atlantic Coast which could be correlated with work in the Southwest or on the Pacific Coast, and which might be related to extension of investigation in Early American and Latin-American history carried on by the Institution, preliminary examination of opportunities for study in the region about Saint Augustine, Florida, was made some years ago. Fortunately, Saint Augustine has itself given attention to questions of this nature, and especially

through the Saint Augustine Historical Society, which has celebrated recently the fifty-third anniversary of its founding.

Subsequent to initiation of the first studies on the Saint Augustine situation, the Honorable Walter B. Fraser, Mayor of Saint Augustine, brought to attention of the Carnegie Institution the fact that he had been authorized by the City Commission to appoint a national committee to study the problem of maintaining and protecting the principal historical values of the city. In development of the program authorized by the city, the Carnegie Institution was invited to cooperate, since whatever information regarding historical features in Saint Augustine could be secured by the Institution would be helpful in carrying out the program of the city. This cooperation has been advanced during the past year by appointment of a committee of the Institution to advise regarding studies of value in developing acquaintance with the early history of Saint Augustine and its immediate environment. To further this work Verne E. Chatelain was appointed a Research Associate of the Institution, and was authorized to make the results of his investigations available to the city of Saint Augustine in advancing such a program as would maintain the historical remains of the region and give them adequate interpretation.

Studies carried out at Saint Augustine during the past year have resulted in locating documentary materials not only impressive as to extent of the data, but also of significance by reason of the fact that they have been little known. A beginning has been made on the assembling of data from these sources, on their careful organization, and on interpretation of the materials. Church and gov-

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ernment archives at Saint Augustine, Tallahassee, and Pensacola have furnished data available in Florida. Additional materials are available in Washington, D. C. Other documents are at Madrid, Salamanca, and Seville in Spain, at London, England, and at various other centers of research in Europe.

One notable instance of data which will have considerable value in any extended study of the Saint Augustine region is found in the Saint Augustine Catholic parish records, of which fourteen volumes of original records are available, covering the period from 1594 to 1763 and representing the oldest records of this type in the United States. Through cooperation of the National Archives in Washington, careful treatment of the original parish records has given them an approximation to permanence, thus facilitating their future study. Photostat copies of these records have been deposited with the National Archives in Washington and with the Saint Augustine Historical Society.

From the point of view of the city of Saint Augustine in its effort to maintain historical values in that region, it has been essential that something be done toward location, protection, and interpretation of the large number of physical remains and relics so characteristic of the area. The materials available range from the splendid ruin of Fort Marion, now cared for under administration of the National Park Service, on through a large number of ruins dating from the Spanish occupation in and around the city, to ancient residences and other buildings representing a long period in the story of the city.

The Saint Augustine national committee has devoted itself to the idea of finding means by which the large

number of historical relics can not only be preserved and protected, but can be so interpreted to visitors that the story of the city, from pre-Columbian occupation by aboriginal Americans up through occupation by Spanish, French, and English, and on into history of the old South and up to the present, can be presented in a clear and convincing way. The proposal to carry forward such a program as is urged by the city of Saint Augustine is worthy of cooperation from all scientific organizations able to furnish data and to help in the interpretation of what is secured.

If the plan outlined can be carried through, it will be one of the most interesting efforts in this country to provide a reliable background of history, extending over four centuries, in a living city occupied by people interested in their own story. The citizens are desirous of seeing that the steps and stages of progress in Saint Augustine through the past be followed by other advances in the future. In some measure these later movements may be guided by a plan for the city designed to express the natural constructive development coming out of a past which is rich in events having direct bearing upon the general problem of history in this country.

Research on physical features involving the study both of aboriginal remains and of relics or structures representing the Columbian civilization has included a sampling or testing study of certain major features, such as the moat surrounding the old city. Investigations of the moat have brought out extremely interesting data, including location of the redoubts and stockades, together with information making it possible to map all major features of the moat and related structures. Studies have also



been made on plans and maps of the city checked against the physical features available today, and on the development of architectural types through the period of occupation by Europeans extending from the Spanish period to the present.

Study on growth of the city has developed through securing of maps and plans of the physical features of Saint Augustine, beginning with the aboriginal villages and extending up through the periods of occupation by Europeans. Many valuable maps, drawings, and photographs have been located, and the features on these documents have been checked against the present landscape, furnishing together an extremely interesting story of evolution of the city.

Research on architectural types has involved location, photographing, careful measurement, and description of all available buildings representing important stages in development of the city. These records have been utilized already in the interpretation of certain aspects of the story of Saint Augustine. The material is extensive, but has been well organized, and will provide data for a wide variety of studies on the history of the city.

#### BEGINNINGS OF HUMAN HISTORY

Assistance and cooperation have been given for a number of major projects in the study of early man, both with reference to the advance of knowledge on the beginnings of human history for the world as a whole and with the special object of furthering research relating to human occupation of America.

Contribution toward work in the Old World has centered principally upon the activities of Dr. H. de Terra

in advance of his studies on the early man problem in India and southeastern Asia, and upon the work of Dr. G. H. R. von Koenigswald in special studies relating to *Pithecanthropus* of Java, commonly recognized as the oldest known human type.

An extensive report by Dr. de Terra on studies covering geological history, associated faunas, and investigation of the culture of early man in northern India has been prepared. In these investigations Dr. de Terra has had the cooperation of a number of the leading investigators of the world, so that his report represents the focus of opinion from outstanding studies in this field. Continuation of the work by Dr. de Terra during the coming year will include investigations in southeastern Asia which should bring about correlation of the principal elements in history of early man in India, China, and Java. Such an advance would have great significance in defining the geological periods, ages of human culture, and the natural succession of life in the Asiatic region.

With aid from the Carnegie Corporation of New York, arrangement was made during the past year for cooperation with Dr. G. H. R. von Koenigswald, of Bandoeng, Java, for further study on the problem of *Pithecanthropus* in Java. In spite of the fact that *Pithecanthropus* is generally recognized as the earliest and most primitive human being, relatively little information has been added in recent decades to the original contribution on this interesting type. After a conference in America on implications of the *Pithecanthropus* problem, Dr. von Koenigswald returned to Java by way of China for the purpose

**Work of  
de Terra  
in India**

**Koenigswald's  
Research on  
*Pithecanthropus*  
in Java**

of studying the original locality and materials of *Sinanthropus*, in order to obtain a better understanding of relationships between *Sinanthropus* and *Pithecanthropus*, and with the special purpose of determining whether these types possibly represent approximately the same level of evolution.

After a very satisfactory visit to the *Sinanthropus* locality and an excellent opportunity for study of the original materials, Dr. von Koenigswald returned to Java, where he has secured two very important specimens from the *Pithecanthropus* region. One of these finds consists of a lower jaw which from its character seems to represent *Pithecanthropus*. This jaw is very heavy, with large teeth, having resemblance in various characters to several of the most primitive human types. The other specimen consists of a considerable part of a skull, much broken, but showing in general the characters of the original *Pithecanthropus* as represented by the skull-cap discovered in Trinil, Java, by Professor Dubois. Parts of the skull not heretofore known are typically human in some of the most important characters; certain other characters resemble those of the apes. Dr. von Koenigswald considers that these new finds show that *Pithecanthropus* is human and that it is the most primitive fossil man known.

Cooperation during the coming year between Dr. von Koenigswald, Dr. de Terra, and others who will be examining the formations in which *Pithecanthropus* has been found in Java, and who will also be carrying the correlation of geological deposits and their contained life through from Java to southeastern Asia, China, and India will undoubtedly give a still better picture of the historical

problem of *Pithecanthropus*. If in these explorations additional material of *Pithecanthropus* should be discovered, we may look for a much better understanding of this earliest recognized stage of man than has heretofore been possible.

Studies relating to the beginnings of human history in America have involved cooperation with a number of investigators and institutions. These researches include study of actual skeletal remains of man and of implements or artifacts produced by him, investigation of the paleontological succession of life stages during those late geological epochs in which man may have been present in America, the physical or geological history of man's possible environment in America, and the history or evolution of climate during the epochs in which he was present.

With reference to the geological background of human history in America, or the geological book out of which the record is read, much still remains to be done in compilation of evidence relative to the epochs or stages included in what we call early Recent, the Pleistocene immediately preceding the present, and the Pliocene immediately preceding the Pleistocene. We can not hope to have a satisfactory story of man in America, or in any part of the world, without a perfectly clear record of geological events from which the account is to be read. Fortunately, one of the most difficult parts of history relating to the physical background of man's story, namely, the stages in climate, is being studied in a very satisfactory way by Dr. Ernst Antevs, who has worked in cooperation with the Institution in recent years on problems concern-

ing climate in geology with especial reference to the story of man.

The succession of life forms or faunas and floras in later geological periods is an essential part of the record which must be available if the story of man is to be secured. Fortunately, the work of a number of leading investigators in this country has been devoted to these problems, and through the work of Dr. Chester Stock of California Institute of Technology with his associates and Dr. Ralph W. Chaney of the University of California with his associates we are gradually accumulating a good record of the types of life known, and of their succession in time.

With reference to the story of man himself, and his relation to the geological record and to nature, rapid advance has been made in recent years at many localities, but more especially in the western half of the continent. Evidence has appeared indicating the presence of man at a time in general earlier than the stage which has been considered commonly as that of man's appearance. Skeletal remains are rare; artifacts of various types are not uncommon; the total record is of much importance.

Unfortunately, the problem of early man in America has been somewhat confused by failure to appreciate the fact that in study of the American problem one is not necessarily concerned with the question of the origin of man, but is first of all interested in when man appeared in America, whether he originated here or in some other part of the world.

One of the most interesting discoveries of human remains in America during the past year has come out of research by Dr. L. S. Cressman, of the University of



Oregon, working in cooperation with the Carnegie Institution on localities in eastern Oregon. A skull and skeletal remains obtained by Dr. Cressman in Catlow Cave were found embedded in a few feet of beach material consisting of well-rounded cobbles, and boulders, and dust derived from soft lenses in the cave walls. This beach marked the highest level of the Pleistocene (pluvial) valley basin. The human bones occurred at a depth of six to twelve inches. The beach material is practically non-stratified and therefore disturbance of it would not be discernible. As a consequence, nothing compels the conclusion that the human remains were embedded when the beach was formed.

The occurrence of the Catlow Cave skeleton marks an early period. Whether the bones reached their present position during the time of the Pleistocene beds, or whether they were placed in the deposit later, may be a subject for future discussion. The occurrence is at any rate of great interest and importance. At the request of Dr. Cressman, Dr. Ernst Antevs, the distinguished student of Pleistocene deposits and climatic changes in that period, was requested to visit the locality and to check the items reported relative both to occurrence and to age of the deposits, and it is from Dr. Antevs' report that the above comments as to occurrence were derived.

#### CONTRIBUTIONS TO HISTORY OF THE EARTH AND ITS LIFE

Studies in the broad field of geological history with particular reference to the succession of life forms through the ages have been conducted in cooperation with a number of institutions, including especially members of the staff of California Institute of Technology, Edwin D. McKee, Naturalist of the National Park Service at Grand

Canyon, and Dr. N. E. A. Hinds of the University of California.

The most critical geological researches are those by Dr. Ian Campbell and Dr. John H. Maxson, of California Institute of Technology, directed toward study of a section of the Archean or oldest rocks present in the Grand Canyon, along the course of the Colorado River in the Canyon. The procedure in these investigations has been worked out with great care, and results of the present season's work will undoubtedly furnish material of the first order of importance.

The study by Dr. N. E. A. Hinds on Algonkian rocks, constituting the next stage above the Archean at Grand Canyon, has been carried on with a view to working out the difficult problem of correlation of these formations with stages in geological sections known from other regions. This work is furnishing a very significant contribution to study of the earlier history of the earth.

The work by Mr. Edwin D. McKee at the Grand Canyon on formations in the upper part of the major Canyon section has contributed very valuable data on the nature and mode of deposition of these formations, as well as on their correlation and the faunas which they contain. The studies by Mr. McKee are in process of publication, and will constitute an important addition both to knowledge of the Grand Canyon section, and to the geology of western North America.

Researches on the sequence of faunas of the later geological formations of the west coast region have been carried out at California Institute under the guidance of Dr. Chester Stock. The gradual accumulation of material, with the intensive study and classification of the types

of life secured, is showing us a life succession which, taken with other data known from western United States, will help to give us a story of the life sequence in the higher vertebrate forms ranking among the most important in the world.

### PUBLIC RELATIONS

Satisfactory progress has been made in the past year in study of problems concerning responsibilities of the Institution to the public. Intensive study on announcement of results from research has been directed mainly toward improvement of quality. Serious thought has been given also to the question of methods by which contributions of research can be so formulated as to give maximum opportunity for the interested public to secure and appreciate the values presented.

Early in the year the small auditorium and exhibit building on Mount Wilson was completed. The program made possible by this new equipment has been in use through the summer and fall and has proved extremely valuable in aiding visitors to obtain an idea of the work conducted by the Observatory and the results obtained. Large groups of visitors have heard the lectures in the auditorium and have studied the exhibits representing major discoveries in current work. The lectures and exhibits have been conducted in such a manner as to articulate with the plans for giving to visitors opportunity to see something of the great realities in astronomy through the 60-inch telescope.

In the present year it has been possible to bring to realization the plans long under consideration for an addition to the Administration Building in Washington such as would increase facilities for bringing about cooperation

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among the departments, and for advantageous handling of programs of lectures, exhibits, and conferences. The new building will include an auditorium of sufficient size to accommodate audiences such as have shown interest in the lectures presented by the Institution in past years. The exhibit rooms will not only permit a better type of exhibition at the time of the annual meeting of the Institution, but will also make possible maintaining here through the year certain exhibits of unusual interest.

Conference rooms will facilitate the furtherance of discussion and conference on major problems of the Institution and cooperating agencies. Additional office space will accommodate investigators, and furnish space for committees studying Institution problems. There will also be room available for such needs of departments as desire from time to time to carry on studies in Washington.

### SPECIAL FUNDS

Three funds built up gradually over the years have played an important part in maintenance of security and in furnishing opportunity to take up major activities requiring larger sums than can be secured ordinarily in the readjustments of an annual budget. These funds have been obtained from income through accumulation of annual appropriations plus additions by return of interest earnings to the funds.

Although special policies are purchased by the Institution to cover liability risks, the Institution has in the main carried its own insurance. Contributions to the Insurance Fund were continued by appropriation until the total sum available with accumulated interest seemed adequate to cover major require-

Insurance  
Fund

ments. Total contribution by interest has greatly exceeded that obtained through appropriation, and since 1929 annual additions to the Insurance Fund have come entirely from interest savings. The total accumulation from appropriations, increases by sale or redemption of bonds, and from interest has amounted to \$771,665.21, against which there have been charged losses and insurance premiums of \$120,064.77, leaving at the present time a sum of \$651,600.44, available for general insurance purposes within the Institution.

The Special Emergency Reserve Fund was established in 1927 for the purpose of providing a safeguard against losses or reduction in value of assets, and as a fund upon

**Special Emergency  
Reserve Fund**

which it would be possible to draw for items too large to be covered in the ordinary annual budget without readjustments unfavorable to regular activities of the Institution. In the past ten years through appropriation, transfer from other available funds, and interest earnings plus increase from sale and redemption of bonds, a total of \$772,824.41 has been accumulated. Against this amount special charges have been made totaling \$236,250 for projects such as repairs to the ship *Carnegie*, construction of the laboratory for Plant Biology, a new power plant for the Geophysical Laboratory, auditorium and exhibit room at Mount Wilson Observatory, and the construction of special apparatus for study of nuclear physics at the Department of Terrestrial Magnetism.

The availability of this fund has also made it possible to finance the project for erection of an addition to the Administration Building, opening the way for improvement



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in the public relations program of the Institution and helping to meet other urgent needs.

Charges against the Pension Fund of the Institution are met through accumulation of annual appropriations

**Status of Pension Fund** for pension purposes plus interest upon the total fund together with small increases made available through reinvestments. It was necessary to increase the contribution of the Institution to the Pension Fund by 25 per cent in 1930 and again in 1932 by 20 per cent to meet requirements arising from the increasing number of members of the staff reaching the age of retirement. Many members who have retired in recent years did not enjoy the benefit of annuity provision in the early periods of their service, and have consequently been granted annuity payments directly from the Pension Fund, supplementary to the relatively small amounts accumulated to their credit from joint contributions since 1919 when the Institution's Annuity Plan went into effect.

The increase in the main cost due to supplementary annuities may continue through the next six years, after which the number of persons who will have had a considerable period of service before establishment of the pension system will diminish. New demands upon the Pension Fund may then result only from addition to the total number of regular members of the staff or from increases in salary.

While it is possible that moderate increase in the contributions by the Institution to the Pension Fund may be needed within the next six or seven years, it is probable that the present method of financing the Pension Fund program and the present contributions will carry all obligations contemplated by the present Annuity Plan of the Institution.





## REPORTS ON INVESTIGATIONS





## DIVISION OF ANIMAL BIOLOGY

GEORGE L. STREETER, CHAIRMAN

There has been some difference of opinion in medical circles as to how rigidly we should define our research programs. Pressing objectives are there without doubt. The difficulty lies in the characteristics and limitations of those who are expected to attain them. The question is raised as to how much freedom should be given to the independent investigator. In view of the intricacy of the process of discovery there is some doubt as to how closely an investigator, or group of investigators, should adhere to a direct attack on a specific objective. For instance, if we wish to find the cause of cancer should our whole effort be concentrated in great institutes organized solely for that purpose? In a sense this is regimenting science, and efforts of that kind in medical research have heretofore been disappointing. It is, therefore, of interest to point out that in the Department of Embryology, where studies are being made in the general field of the structure and physiology of the living cell, it has come about that the tumor cell has been the object of considerable study; and it was chosen because it offers certain advantages for the study of cell activities. Observations have been made, however, which are fundamental to the cancer problem. For example, crucial evidence has been obtained indicating that the malignant cell is a permanently altered one that breeds true. After such malignant cells are once established they multiply independently of the agent or environment which produced them and their growth can be continued indefinitely by transplantation from animal to animal and by means of tissue cultures. Furthermore, in the same laboratory it has been found during the past year that the presence of growing malignant tissue results in an increase in one of the varieties of white blood cells both in the peripheral blood and in the blood-forming organs. This phenomenon is characteristic for certain tumors and such tumors are transplantable into mice of the same strain. The host's resistance, however, can be altered as well as the strain specificity of the tumor itself.

At the same time a group of workers in the Department of Genetics has been studying the occurrence, transmissibility, and pathology of leukemia as it is found in mice. This is not cancer, but it is a malignant growth and, in a way, a tumor. Leukemia differs from cancer in that the leukemic cells in their various stages of development are cytologically normal, but they differ from the normal in their rate of differentiation. Malignant lymphocytes differentiate more slowly than normal ones. This results in the accumulation of large numbers of the more primitive cells, although a certain number of fully mature cells are constantly being formed. The rate of differentiation appears to be related to the degree of virulence. The slower the development, the more virulent is the population, and the larger is the proportion of primitive cells and the more rapid is their increase in number. As a whole the population is leukemic, but as individual cells they appear to be normal in all respects except in their rate of differentiation.

Other studies on mouse leukemia are being made with a view to determining the operation of genetic variables and specificities. The conditions

have been determined by which resistance to leukemia can be set up by repeated sublethal doses of leukemic cells themselves, also resistance to transplanted leukemic cells has been induced by treatment of the host with embryonic tissue. It has thus been possible by varying the experiments to test the relative values of the many factors involved, namely, genetic constitution of the host, modified constitution of the host, intrinsic properties of the leukemic cells, modified virulence of the leukemic cells following repeated transplantation, and genetic constitution of the embryos that supply the embryonic tissue. It is quite evident that these breeding and inoculation experiments at the Department of Genetics and the tissue-culture and tumor-transplantation experiments in the Department of Embryology are producing some of the fundamental facts upon which an understanding of the nature of cancer must eventually rest, even though these facts are but a by-product of what a medical man would probably designate as pure research, meaning research for research's sake.

The studies which have been mentioned have been made by different groups of workers primarily independent of each other. They concern related problems but are approached from different angles and so are complementary. It is obvious that intercommunication between the groups should be frequent and full, in so far as this can be brought about without infringement upon the backgrounds and approaches of the respective groups. Such an intergroup awareness is facilitated by our administrative organization as a division, and the distance separating Baltimore from Cold Spring Harbor is not allowed to be a barrier.

In the field of endocrinology, items will be found in the reports originating from the Department of Embryology, the Nutrition Laboratory, and especially the Department of Genetics. In each case there were special circumstances that stimulated and determined the character of the investigations. It is to be noted that just as tissue cultures of mouse tumors have given us basic information regarding the cancer problem, so the material secreted by the crop gland of pigeons is providing us with a means of solving some of the most interesting problems of the ductless glands. It is through this agent that doubt has been thrown on the separateness or singleness of a "growth" hormone in the pituitary gland. Among other endocrine studies, an important advance has been made in our knowledge of the regulation of calcium metabolism. It has been found that the sex hormones produced by the ovary increase the amounts of calcium in the blood. Since this function is not apparently shared by the testis, it may provide us with an explanation for sex differences in our skeletal and mineral constitution. If the sex cycles of females involve interruption of calcium deposit, this in turn should be an important factor in the shorter stature of females, and of some races as compared with others. The study of racial physical characteristics is also being continued through the methods of the physical anthropologist, and along with this, tentative efforts have been made toward devising psychological tests of mental characteristics of some of the primitive human races.

Another very complicated field in which diverse approaches are called

for is that of the physical expression of the gene and its bearing on the structure of chromosomes. In the Department of Embryology the fly *Sciara* has been the material chosen. It possesses the advantage of having very large salivary chromosomes that are especially suitable for cytological study, and thus the experimental studies made upon it deal chiefly with chromosomal structure. *Sciara* possesses the disadvantage, however, of not being so thoroughly known genetically as *Drosophila*. For the latter we have chromosomal maps on which a considerable number of deficiencies have been located by genetic means. In the Department of Genetics *Drosophila* has been the chosen material, and the background and objectives of this Department's experimental procedures are thereby more or less determined. It is clear that genetic methods alone are too crude for the final analysis of many genetic changes. To determine what actually happens when a change in a chromosome occurs, we must resort to its detailed cytology. There must be a close coordination of genetic and cytological studies if we are to understand the nature of genetic changes, and this we are attaining by the maintenance of different research groups.

The fact that each "giant chromosome" of *Sciara* is really a pair of homologous chromosomes fused side by side has made it possible to analyze small differences in these components, and it is hoped that in this way the ultimate unit may be disclosed. There is considerable evidence that the idea of a multiple threadlike structure (chromonemata), which had been postulated for the chromosome, must be revised. If the giant chromosome were simply a cable of component fused chromosomes, its size would require a number that is greater than can be accounted for. From the genetic side, the group working with *Drosophila* have made many experiments with refined methods of radiation. From their observations on the effect of soft rays, the dosage-effect curve for chromosome breaks, and the fact that the injury is influenced by biological factors, it becomes probable that in radiation experiments the genes are affected indirectly through changes produced in their environment. A study has also been started on the effect of neutrons. This was made possible through the cooperation of the Department of Terrestrial Magnetism. In the preliminary tests for the frequency of X-chromosomal lethals it was found that hereditary changes can be produced in this way and that the effectiveness of the neutron treatment increases with the dosage applied. From the physical standpoint it is expected that neutrons will produce changes that are different from those caused by X-rays, and some clue may thus be obtained as to the mechanism by which such changes are produced.

The field of genetics continues, as heretofore, to supply problems of varied nature. In the Department of Embryology a genetic study of five years' duration on the fly *Sciara*, involving six new wing characteristics, has been completed. In the same Department experiments have been continued on hereditary vulnerability to dietary defects. In the Department of Genetics the study of the chromosomal differences between the herbaceous species of the genus *Datura* has been continued along with a summary of the geographical distribution of its different chromosomal races. Two new pure-



breeding types of *Datura* have been synthesized and "bud sports" have been collected and studied. A most promising experiment has been made in influencing chromosome behavior by the use of chemical treatment of the buds. It appears to be a method by which one can cause doubling of the chromosomes in buds of adult plants. If further experience with this method comes up to our expectations, it will have considerable practical importance.

In the field of eugenics, basic studies have continued on the resemblance of the racing capacity in the thoroughbred foal and its near kin, with a view to determining the net resultant of such relationships on the foal. By such computations a prediction can be made as to the probability that the racing capacity of the foal will fall within a given racing-capacity range. For the convenience of breeders these computations have been simplified into probability tables and issued in book form, the "Brown Book," from which one can predict the racing capacity in the foal for any one of twelve near blood kinships.

Departing from the horse, where the inheritance of behavior could be accurately studied because of the extensive and precise records that are available for this animal, attention has been given during the past year to a survey of the state of Connecticut with respect to the source, the increase in number, and the cost of the inadequates among the state's population. This survey is being made in collaboration with a commission appointed by the state of Connecticut, and in its fundamental character is a pioneer undertaking.

Important anthropological studies have been completed in fetal growth, notably in the primates. Studies have been made of the body proportions in fetal and adult gorillas and chimpanzees. A study has been made of the relationship of man to the anthropoid apes which permits the construction of a three-dimensional genealogical tree.

Among other studies, the anatomical group has been particularly active in a comparative study and analysis of the muscular system which will enable the adoption of a phylogenetic basis for the grouping of muscles, in place of the regional or topographical one now in general use. The important program being carried out on the structure and function of some of the main sensory-motor systems of the central nervous system has been continued during the past year. Experiments have been made which deal particularly with the organization of the pyramidal and extrapyramidal activities. The information thus obtained has led to a fundamental advance in our knowledge of this important mechanism.

The approaching change in régime at the Nutrition Laboratory has more or less influenced the recent activities of that group. It has been necessary to bring to completion a number of programs, and this has involved a concentration upon the preparation of a vast amount of data for publication. When this is finally assembled it will constitute the record of a striking period of productivity. The numerous cooperative investigations in which the unique methods and resources of this Laboratory are made available to nonresident workers have been continued as heretofore. For the most part these are researches of short duration. The cooperation with the Uni-

versity of New Hampshire is more comprehensive, and the possibilities of its results being of specific value to man justify its continuation over a period of years.

During the past year the Tortugas Laboratory suffered the loss of its Executive Officer, Dr. William H. Longley, who died in Baltimore on March 10, 1937, following an illness of several months' duration. Dr. Longley had been associated with the work of the Tortugas Laboratory since 1910, and since 1922 he has served as Executive Officer as the successor of Dr. Alfred G. Mayor. The readers of the Year Books since that time will not need to be told that he filled that position conscientiously and in an effective manner. Through him the Mayor traditions were carried on and under his leadership the Laboratory was visited each year by competent investigators from this country and abroad, who found there an atmosphere of genuine and enthusiastic devotion to research and a pervading web of cordial helpfulness which bound the group together in their progress toward a more or less common goal. Dr. Longley left a partially completed manuscript along with voluminous notes and photographs, from which it is thought there can be completed a monograph on the ecology and classification of the tropical reef fishes, a subject to which he had devoted his interest throughout his whole period of association with Tortugas.

Dr. Longley was succeeded as executive officer by Dr. David H. Tennent, by whom the 1937 season of the Laboratory was directed. During the twelve weeks of its operation it was visited for longer or shorter periods by nineteen investigators, two of whom were from England and one from Belgium. The investigations carried on during the summer include: physiology of *Valonia*; influence of carbon dioxide in the effect of light on the electromotive force of *Valonia*; photodynamic effects of vital dyes; implantation of embryonic fish tissue; oil-cytoplasm interfacial tensions; rôle of mangrove vegetation in land building; studies on coral reefs; swarming of the Atlantic palolo; experiments on ascidians; the ciliates of sea urchins; function of fin movements in equilibrium of fish; development of the dorsal spine in the sting ray; regeneration in holothurians; development of chela in Crustacea under gamma radiation; and tumors of fishes.

In his brilliant biography the distinguished Spanish histologist Ramón y Cajal relates the difficulties he had in convincing investigators "long since devoted to the defence of erroneous facts and gratuitous hypotheses" and adds that in the realm of thought as in that of material things the law of inertia is the great obstacle which has to be overcome. With full realization of this human trait, the embryological group is fortifying itself in its approaching encounter with the deeply entrenched three-germ-layer doctrine by securing a sufficient number of stages to check every phase concerned. The phenomena which this doctrine is supposed to regulate fall within the early steps of development, for which little or no primate material had been available, nor very adequate material for other mammals. Our success in obtaining this missing evidence enables us to restudy the whole problem of the origin of body tissues. An outstanding example is



that of the yolk-sac. It has been found that the yolk-sac is not important as a container, but as a specialized nutritional membrane which in some types becomes elaborated into an extensive placental structure. The cavity underlying this membrane opens so widely into the gut cavity that the two have been generally treated as a common cavity. We have found, however, that from the very beginning one can distinguish two distinct types of tissue bordering this dual cavity and each having a different source of origin. One of these constitutes the gut endoderm, which arises in association with the embryonic ectoderm, and the other is the yolk-sac endoderm, which belongs to the primitive mesoblast and is essentially trophoblastic. The gut and yolk-sac are thus different in origin and are always abruptly demarcated from each other. The one becomes a definitive part of the embryo and the other is an auxiliary organ to be discarded at birth. We have now obtained specimens which show the very first steps in the laying down of the yolk-sac wall, and we are in a position to describe the process in detail and without resort to diagrams and hypothetical transitional stages. The reader of the following report will find, in addition to various studies of the structure of the embryo, several interesting studies covering the functional activities of embryonic organs.

Under the Division of Animal Biology are included the various biological researches conducted by the Institution and primarily concerned with the physiology, anatomy, embryology, evolution, and heredity of animals. As far as possible the various projects are located where they can be best conducted. The principal groups included in the Division are the Nutrition Laboratory, located in Boston; the Department of Genetics, comprising the Station for Experimental Evolution and the Eugenics Record Office, both located at Cold Spring Harbor; the Department of Embryology, in Baltimore; and the Tortugas Marine Laboratory, on Loggerhead Key, Florida. In the following report each group or subgroup has supplied the account of its own activities for the year and the respective accounts should be read in their entirety, rather than placing any importance on the above summary, which is necessarily sketchy and incomplete.

DEPARTMENT OF EMBRYOLOGY<sup>1</sup>

GEORGE L. STREETER, DIRECTOR

## EARLY EMBRYONIC STAGES

At the beginning of last year our collection of macaque embryos of known age consisted of sixty-four specimens most of which were prepared in serial sections suitable for microscopic study. The collection was sufficiently complete to yield the outlines of the story of development from the ninth day to those older stages where the organs have attained their main features. On closer study it was found that before an account worthy of its importance could be given of the embryology of this close relative of man it was necessary to have information on certain details which were only to be had from intervening stages not yet represented in the collection. Consequently early last fall we set ourselves to the task of supplying the missing items. The chief desideratum was confirmatory and closely overlapping material of the eleventh to the thirteenth day. In spite of the difficulties and the vulnerabilities of the embryo during this particular period some twenty specimens were obtained during the months of October, November, and December. Some of these proved to be abnormal, some were mechanically injured, and some were a little too young or old. Eight of them, however, were just what we needed and these gave us our desired information. Considerable progress has been made in the study of our embryos and the preparation of a monographic report on their embryology is now engaging our attention.

## ORIGIN OF THE YOLK-SAC

So strong is the craving for morphological uniformity, such as is implied in the prevailing phylogenetic interpretation of animal relationships, that it has given rise to a tendency among embryologists to be alert for evidences of recapitulative processes whenever confronted by new material and new structural arrangements. Their zeal in detecting features that confirm the phylogenetic law has been greater than their curiosity concerning the actual detailed development of specialized forms. Interpretation has outstripped observation.

In this laboratory we are having the opportunity of studying a considerable number of hitherto unavailable early stages of the primate embryo. The material is all dated, well oriented, and ideally prepared for microscopical study. In our desire to make our observations worthy of this unique material we have sought to correct the tendency referred to above and are deliberately approaching the macaque embryo in an objective manner and as far as possible without bias or preconceived theory. We are trying to describe it with fresh eyes and without regard to what is reported of other embryos. In doing so, minimal use is made of hypothetical transitional stages; attention is being concentrated on structures and evidences of processes that can actually be seen and photographed, and we are preferring terminology that is free of theoretical implication. The wisdom of this

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restrictive manner of study and presentation will be determined by its ultimate usefulness. However, if we can adhere to actual embryological structures and to closely overlapping steps in their developmental alterations it is felt that a considerable contribution to embryology will be attained whether our presentation is in accordance with a good plan or not.

In a previous report (Year Book No. 34) the developmental behavior of the amnion was outlined and it was pointed out that contrary to conventional ideas the amnion is a derivative of the trophoblast and thus an auxiliary constituent of the ovum and not a definitive part of the embryo. The amniotic cavity embryologically is duplex in origin, whereas functionally it appears to have but the simple rôle of a serous cavity.

Even more unconventional is our interpretation of the formation of the yolk-sac, as forced upon us by our material. It is to be pointed out that the mammalian yolk-sac is not important as a container, but as a specialized nutritional membrane which in some forms is elaborated into an extensive placental structure. The yolk-sac cavity opens so widely into the gut cavity that the two have been commonly treated as one. We have found that from the very beginning one can distinguish two distinct types of tissue bordering the cavity, having different sources of origin. One of these is the gut endoderm which arises in association with the embryonic ectoderm, and the other is the yolk-sac endoderm which is closely related to the primitive mesoblast and the other trophoblastic elements. The gut and yolk-sac are thus different in origin and are always abruptly demarcated from each other. The one becomes a definitive part of the embryo and the other is an auxiliary organ which is discarded at birth. Among the specimens obtained during the past year are some that show the very first steps in the laying down of the yolk-sac wall and the formation of a common cavity between it and the early gut endoderm. It may be added that the same precocity of oral parts as compared with more caudal parts is found to occur in the yolk-sac, similar to the cephalo-caudal gradient that is so conspicuous in the central nervous system and the alimentary tract.

#### DETERMINATION OF THE AXIS OF THE GERM-DISK

Basing his study on a series of fourteen macaque embryos, from the ninth to seventeenth day, Dr. C. H. Heuser has found that the formative cells, which are arranged as a spherical clump on the ninth day, become an elongated clump soon after and therewith exhibit the differentiation of a head end. The embryos without exception undergo this axial elongation, before the embryo has acquired its flattened germ-disk character. The primitive streak can be identified at about the thirteenth day. At first it is an oval area and mesoblast cells can be seen between the gut endoderm and the overlying ectoderm. Graphic reconstructions show that the mesoblast cells are much more numerous in the caudal half of the germ-disk and from there they spread laterally and forward as they do in the pig and many other mammals. The primitive node is distinguished from the primitive streak by appearing later. It is present, however, on the seventeenth day.

## DEVELOPMENT OF CAROTID BODY IN MAN

The development of the carotid body in the human embryo was studied by Dr. J. D. Boyd as a Fellow of the Rockefeller Foundation during the winter 1934-1935, and his observations were based on the examination of serial sections of a large number of embryos varying from 4 mm. to 103 mm. crown-rump length. This study was mentioned in a previous report. During the past year a complete account of his observations and analysis of the problem appeared together with illustrations in the "Contributions to Embryology." Dr. Boyd succeeded in showing that the cells of the carotid body pass to it from the ninth and tenth cranial nerves and from the cervical sympathetic trunk. But also a mesodermal condensation related to the third branchial-arch artery is concerned in its development. It is into this mass that the cells of nervous origin pass in the later stages. Its relation to the third branchial arch appears to be significant. Apparently in all air-breathing vertebrates a structure of this kind is found in connection with the third branchial-arch artery, with a nerve supply connected with the pressor-receptor zone of the artery. At least in part it has a sensory function and Dr. Boyd concludes that it is a chemo-receptor. He also points out the apparent serial homology between the carotid bodies and the aortic and pulmonary paraganglia.

## PHYSIOLOGY OF THE EMBRYO

Using phenol red as his indicator, Dr. I. Gersh has shown that structural differentiation marks the time in pig and other mammalian fetuses when the proximal tubules of the kidney begin to eliminate the indicator and when water is reabsorbed by these tubules and by the loop of Henle. But this is only one of the important results of Dr. Gersh's study of the correlation of structure and function of the kidney and its puzzling associate and predecessor, the mesonephros.

In his studies of the mesonephros, or embryonic kidney, and the metanephros, the permanent kidney, Dr. Gersh employed an adequate technical procedure involving the use of chemical indicators as tests of tissue function. For glomerular activity he used sodium ferrocyanide, which in the adult is entirely eliminated by the glomerulus. For activity of the proximal convoluted tubules he used a non-toxic phenol red. These were used in various types of mammals and at various fetal stages. He found that ferrocyanide, as soon as its elimination begins both in the mesonephros and in the metanephros, is found in the glomerular spaces. It seems to be entirely eliminated through the glomerulus as in the adult. Similarly phenol red is eliminated, apparently entirely, by the epithelium of the proximal tubule. Thus Dr. Gersh had tests for the functioning of the principal parts of the nephron.

When his results are tabulated it can be seen that in all the mammals examined the mesonephros functions both in its glomerulus and in its proximal tubule. Furthermore, it continues to eliminate sodium ferrocyanide and phenol red for a time, even after the permanent kidney has taken up the same functions. In all the animals studied, water reabsorption in the metanephros could be demonstrated in the proximal convolution, though it takes place to a much greater extent in the loop of Henle. In



referring to the excretions of the fetal kidneys Dr. Gersh points out that in the chick the fetal urine passes to and is concentrated in the allantoic sac, leaving solids in the cavity which are shed after hatching. In placental mammals, however, the urine passes into either the allantois or the amnion or both. Here both the solids and water are reabsorbed to be eliminated through the maternal circulation.

In correlating the histology of the embryonic kidney tissue with its functional activity, Dr. Gersh finds that the elimination of phenol red is invariably accomplished by differentiation of the cells of the proximal convoluted. Also there is a recognizable morphological difference in the cells of the descending limb of the loop of Henle shortly before the beginning of water reabsorption. In the glomerulus there was no noticeable histological indication paralleling the elimination of ferrocyanide, which in view of the nature of the glomerular membrane is not surprising.

The correlation between structure and function in the developing metanephros has been carried farther by Dr. Gersh and Dr. L. B. Flexner. They undertook the determination of the oxygen consumption of bits of metanephric tissue, in a resting state, as an evidence of its capacity to do work, and to see if this is increased synchronously with the differentiation of active renal epithelium. Their results were affirmative. They found that the appearance of mature structure and the capacity for functional performance of the metanephric tubules is accompanied by an increase in the oxygen consumption of this tissue.

In their experiments these investigators used many litters of fetuses of fourteen different body lengths. The fetal kidneys from these were removed and reduced to small bits for test in the Warburg apparatus. It was first verified that the time intervening after removal and the interruption of circulation did not introduce factors which would not be found in living normal tissue. Also it was verified that the non-secreting tissues (mesenchyme) of the kidneys played a negligible rôle in oxygen consumption and could be disregarded. When the observations are tabulated the results are striking. In fetuses from 26 to 37 mm. body length the kidney tissue shows an oxygen consumption having a mean of 9.3 c.-mm. per mg. dried weight per hour, whereas the kidney from fetuses between 53 and 140 mm. body length has an oxygen consumption varying from 14.0 to 21.9, with a mean of 16.4 c.-mm. per mg. dried weight per hour, which is almost double that of the former group.

#### HEREDITARY VULNERABILITY TO DIETARY DEFECTS

A series of breeding experiments done in collaboration with Dr. E. A. Park and Miss Deborah Jackson, and extending back for several years, was brought to a conclusion during the past year. A preliminary account has been given and the complete records are now being prepared for publication. The records show that at the end of the first month, when their bone development is most active, young rats can be weaned and placed on any desired diet. After a sufficient period of test diet, if one wishes to study the effect of that diet on growth of bone, one can make X-ray films of a selected bone area and record the progress of its development. The animals, after being



subjected for three weeks to a rachitic diet and then X-rayed, are returned to a normal diet and reared, uninjured by the experience. Four months later they are bred. The breeders are chosen on the basis of the X-ray record of their sensitivity to the diet. Following fourteen generations of such selection and inbreeding, two strains of rats have been developed which in all appearances are alike, save in the one character that one of them reacts more severely to a rachitic diet (vitamin-D-free, high calcium and low phosphate) than the other strain. These experiments reveal the plastic nature of the growth line (epiphysis) of bones and its sensitivity to disturbances in the chemical composition of the body fluids. They also support those investigators who claim that heredity is a definite etiological factor in abnormal bone development, of the type seen in rickets. From such experiments we can thus understand why under equally unfavorable conditions the children in some families acquire rickets, while others do not.

#### EMBRYONIC DEVELOPMENT OF THE FRUIT FLY

During the past year there has appeared an account of the embryology of *Drosophila melanogaster* by Dr. D. F. Poulson, who recently has been associated with Dr. Metz in some of his chromosome investigations. The studies on which Dr. Poulson's description is based were made at the California Institute of Technology in the laboratory of Professor Sturtevant. This contribution will be welcomed by the large group of workers who are using this form for genetic research and especially by those who are undertaking experiments in transplantation of organs. In former reports reference has been made to the embryology of *Sciara*, to which Dr. Du Bois added new observations. Her work called attention to our need of a complete account of dipteran embryology. This new monograph by Dr. Poulson in large part fills that gap.

#### CHROMOSOME STUDIES

##### EFFECTS OF MECHANICAL DISTORTION ON STRUCTURE OF CHROMOSOMES

As a means of securing evidence on the structure of chromosomes, Dr. C. W. Metz has studied the effect of mechanical distortion, and of adhesions, on the appearance of salivary gland chromosomes. In particular he has analyzed the evidence as to the artifact nature of the longitudinal striations or threads seen in fixed preparations of chromosomes, and generally held to be chromonemata, or the units of a cable-like chromosome.

In studying such preparations Dr. Metz found that the protoplasm of these giant chromosomes is highly viscous and that it can be stretched into long, delicate strands or threads. These threads can be drawn out laterally or in various directions while connecting with and being indistinguishable from the longitudinal striations known as chromonemata. It was also noted that the chromatic materials are more viscous and more tenacious than the achromatic, but they also may be stretched if subjected to sufficient tension. By means of mechanical distortion it was possible to produce local rearrangements of materials within a chromosome which result in artificial striations which have the same characteristics as the so-called chromonemata. Finally,

the number of strands or striations may vary widely in adjacent regions in the same chromosome, and vary in such a way as to indicate that they are artifacts rather than structures characteristic of the living chromosome.

These experiments of Dr. Metz indicate that the striations, which have been so much discussed, are not chromonemata; and moreover no multiple chromonemata are present in the chromosome, unless they be extremely small and delicate and invisible by means of our present microscopical methods.

#### GENIC AND NON-GENIC MATERIALS IN CHROMOSOMES

The interest attached to the giant salivary gland chromosomes has centered around the possibility that their conspicuous chromatic bands might be the visible representatives of individual genes, or clusters of genes. If that were true, they would furnish us with a more reliable framework, or map, than has heretofore been available on which to plot gene distribution. Moreover, it has been obvious that these large chromosomes consist of two types of material, one of which is chromatic and the other is not. Some investigators have held that the chromatic components are genic, while others have supported the opposite view. Because of the uncertainty attached to this fundamental point Dr. C. W. Metz and his co-workers have been studying the morphological characteristics of both the chromatic and the achromatic elements of the salivary chromosomes under various conditions and in different dipteran forms.

It has been demonstrated by Dr. Metz that the achromatic material is in the form of discontinuous droplets or vacuoles, while the chromatic material lies in the interstices and is essentially continuous. Thus the bands or chromatic disks are separated by intervals of achromatic droplets. The thickness and conspicuousness of a disk depends on how much chromatic material it contains. The chromatic material is not confined to the disks but extends between and around the achromatic droplets which separate one disk from the next. It constitutes a framework somewhat resembling a honeycomb. It is found that wide differences exist in the dispersion of the chromatic material. In some cases the transverse disks are dense and clear-cut, while the intervening achromatic space between them is transparent and its droplet nature obscured. In other cases the chromatic material is more widely distributed and the achromatic droplets become conspicuous because of the chromatin surrounding them. The latter type constitute the "vesiculated" chromosomes, and the former the "non-vesiculated." In normal living chromosomes one appears to be reversible into the other and all intergrades exist. Both types may be found simultaneously in one gland. The exact distribution of the two types of material is evidently not fixed. The fundamental pattern, however, represented by transverse chromatic disks appears to be definite, though variability occurs as to whether they appear single or double and also as to their granular form. What was apparently a single disk can be transformed into a double disk by the acquisition of achromatic material between its two faces. The thinnest disk may in this manner become transformed into a double one

or capsule. There seems to be no distinction between the achromatic material within the double disk and that outside.

The hypothesis that chromatic granules, or heavy-walled droplets as maintained by others, represent individual genes, carries the implication that genes have definite size limits and that growth involves their duplication. Thus a giant chromosome is large because the original "string" of genes of which it was composed has undergone repeated divisions, resulting in something like a cable. The number of granules in a transverse disk was regarded as the index of the amount of multiplication, each granule representing an individual "string." A large body of evidence has been assembled by Dr. Metz showing that this hypothesis does not explain matters. His observations include: discrepancies in size relationship, such as length of chromosomes, number and volume of the granules; also discrepancies from conditions existing in an actual occurrence of compound chromosomes, which will be referred to again in a subsequent paragraph; and discrepancies in the relation between the chromatic and achromatic materials. Dr. Metz concludes that the increase in diameter of the giant chromosome must be explained in the same way as the increase in its length, rather than on the basis of an enormous increase in the number of "gene strings." The longitudinal lines which have been seen between chromatic disks and which were thought to be threads connecting successive granules are regarded as interfaces with more or less chromatic material between the achromatic droplets. These and the striations produced by stretching are explained by Dr. Metz as distortions of the honeycomb-like structure of the chromosome. We cannot yet claim to have our finger on the gene, but a considerable body of information has been accumulated during the past two years regarding the finer anatomy of the chromosome.

#### MULTIPLE CHROMOSOME COMPLEXES

The observations made by Dr. C. A. Berger upon epithelial cells of the larval ileum of the mosquito are of particular interest because of the light they throw upon the structure of giant chromosomes. In these cells Dr. Berger has been able to demonstrate an increase in the number of chromosomes by repeated division, in growing nuclei which appear to remain in a typical "resting stage." Thus, during metamorphosis multiple complexes of 96, 48, 24, 12, and the normal diploid number of 6 chromosomes are found in the epithelial cells of the pupal ileum.

During the larval period the epithelium of the ileum grows by increase in cell size, while the number of cells remains constant. In young stages the nuclei range from 3 to 4  $\mu$  in diameter and at the end of their growth period they have three or four times their original volume. During this period the nuclei and the chromatin consist of a reticulum of delicate slightly granular threads. In the early hours of metamorphosis, however, division and multiplication of these cells begin. With the first division there are found to be 48 and more rarely 96 chromosomes, which explains the large diameters of the larval nuclei, and the number appears to be directly correlated with the size of the nucleus.



As metamorphosis progresses these cells repeatedly divide with corresponding decrease in their size and corresponding decrease in the number of chromosomes until we come to the relatively small nuclei of the rebuilt imaginal ileum. Apparently this anticipatory multiplication of chromosomes during the long larval resting stage greatly facilitates cell proliferation during the subsequent metamorphosis. This work of Dr. Berger is of particular interest because he demonstrates an actual incidence of compounding of the chromosomes, which phenomenon has been suggested as an explanation of the giant salivary chromosomes. At the same time it establishes a reasonable range of such compounding. That is, it is unlikely that this manner of doubling is repeated more than four times. To theorize a much greater multiplication than this, as some have been inclined to do, is no longer justified.

#### CHROMOSOME DEFICIENCIES AND EMBRYONIC DEVELOPMENT

During the past year Dr. D. F. Poulson has completed a study of the effects of certain chromosome deficiencies upon the embryonic development of the fruit fly. He studied a variety of deficiencies involving greater and lesser portions of the X-chromosome, ranging from total absence to a defect involving but a small segment of this chromosome. By appropriate matings, eggs were produced having no X-chromosome. It was found that these do not develop beyond the earliest stages. Cleavage occurs but there is no uniform distribution of nuclei throughout the egg and the normal migration of nuclei to the surface does not take place. For the most part the dividing nuclei remain in the anterior part of the egg as a solid mass. Cytoplasm does not collect around them and no cells are formed. This is followed by disintegration of the nuclei and complete failure of morphogenesis.

Where eggs are deficient for half of the X-chromosome, the nuclei migrate to the surface of the egg and continue dividing. However, they do not accumulate cytoplasm and so do not produce cells. Thus no blastoderm is ever formed and all subsequent development is abnormal.

A lesser deficiency than the above, known as Notch-8 deficiency, was found to result in eggs in which the pole cells and blastoderm form normally and in the early stages there are no externally apparent abnormalities. A little later, however, when the germ band should contract and segmentation should become definite, it is found that the latter does not occur other than faintly. When the eggs are examined in sections it is found that they have formed little or no mesoderm or endoderm; organogenesis is clearly abnormal and such larvæ are non-viable.

Dr. Poulson thus demonstrates that the larger the segment of the X-chromosome missing, and so the more genes lacking, the earlier and more widespread are the evidences of abnormal development. Correspondingly, the smaller the missing piece, the more localized and specific are the effects. Dr. Poulson, who has been working with Dr. Metz during the past year, leaves to become a member of the Department of Zoology, Yale University, at the beginning of the next academic year.

A GENETIC STUDY IN *Sciara*

Following an intensive study of *Sciara coprophila*, over a period of five years, Dr. H. Smith-Stocking has completed an analysis of the method of segregation of the chromosomes in this fly. It was first necessary to obtain a sufficient number of mutant characters to identify each pair of chromosomes, and the relationship of the new characters to each other was then analyzed by means of linkage tests to make sure that all the chromosomes observed cytologically were accounted for genetically.

When her study was undertaken, two linkage groups were already known, one representing the sex chromosomes and the other representing the first pair of autosomes. She now has added to these the remaining pairs of autosomes. Working with six new wing characters, she has shown that the chromosomes in each of them are segregated selectively in the male so that the paternal member, in the first spermatocyte mitosis, goes away from the monocentric pole and is cast off, while the maternal approaches the pole and is retained and transmitted. Thus in all the autosome pairs the male transmits only the maternal chromosome in each case.

Six new wing characteristics were obtainable, all of which proved to be autosomal dominants. Each was shown to segregate selectively in the male in such a manner that only characters of maternal origin are transmitted. In studying their linkage Dr. Smith-Stocking found that all the chromosomes can be identified by means of mutant genes. The complete roster therefore is: chromosome I, truncate wings; chromosome II, truncate, dish, and varied; chromosome III, curly; and chromosome IV, blister, delta, and fused. Because of the great resistance of *Sciara* to radiation it was found difficult to secure satisfactory mutant characters. Furthermore, the normal rate of their spontaneous appearance in nature is low. Hundreds of cultures, obtained from five different localities and cultivated in the laboratory for several years, yielded only three mutant characters up to the time resort was had to X-ray. Those obtained were dominant wing peculiarities.

## STUDIES OF LIVING TISSUES

## BLOOD CHANGES ASSOCIATED WITH GROWING TUMORS

In studying tumors experimentally induced in mice by dibenzanthracene, Mrs. M. R. Lewis has found that the presence of this growing malignant tissue results in an increase in the number of the neutrophile white cells in the peripheral blood and in the blood-forming organs of the host. In other words, these are myeloid-stimulating tumors. The extent of the neutrophilic increase varies according to the particular tumor. Using pure inbred strains of mice, she induced eighty tumors, and these were all transplantable into mice of the same strain and with two exceptions were not transplantable into mice of a different pure inbred strain. If, however, these myeloid-stimulating tumors are repeatedly grafted into mice of another strain, in some of the animals an alteration is produced which permits growth of the tumors to which they had previously been resistant, and also a change occurs in the tumors themselves by which they become transplantable into mice of alien strains. There is alteration both in the host's resistance and in the strain specificity of the tumor itself. Where these alterations occur they are accom-



panied by an especially severe increase of the white cells (neutrophilia) in their alien-strain hosts.

Because of their bearing on tumor formation Mrs. Lewis has continued these experiments, utilizing other strains of mice and also rats. She finds that the adrenal glands of certain tumor-bearing animals become infiltrated with cell masses composed of proliferating myeloblasts, some myelocytes, and many polymorphonuclear cells. These myeloid infiltrations of the adrenals are, however, not present in all the tumor-bearing animals. They appear to be limited to those hosts that respond to the tumor by a severe neutrophilia in the peripheral blood and a myeloid hyperplasia of the spleen, bone marrow, and lymph nodes. Finally, there is the significant observation that whereas this blood disturbance increases with the growth of the tumor, it also subsides in those animals in which the tumor regresses. These blood changes are a factor in the tumor problem concerning which very little has been known.

#### PINOCYTOSIS

The phenomenon by which a living cell extends thin, waving ruffle-like pseudopodia and by that activity encloses and takes within its cytoplasm globules of the surrounding fluid was first fully described by Dr. W. H. Lewis and termed by him pinocytosis, as has been mentioned in previous reports. It is a characteristic activity of normal macrophages and many malignant cells. During the past year he has continued the study of this phenomenon by means of motion-picture records. He finds that within the course of a few hours a cell may drink several times its volume of fluid. It is pointed out by Dr. Lewis that in this manner cells can ingest complex substances in solution, such as proteins, which cannot diffuse into them. It is quite possible that the macrophages which exist in the tissue spaces of the body in enormous numbers may in this way play an important rôle in modifying and maintaining the body fluids in proper condition. This is a field of physiology that must be approached by means of tissue culture in some such way as is being done by Dr. Lewis.

#### METABOLISM OF MALIGNANT CELLS

In cooperation with Dr. J. Victor, of the Department of Pathology, Columbia University, Dr. Lewis has made a series of determinations on the metabolism of pure cultures of malignant cells from a known strain. Observations were made on cultures of different ages and grown in different media.

In the first place, it was found that the duration of the cultures had no effect on their metabolism; no significant difference seems to exist between 268-day cultures and 981-day cultures. In the next place, it was found that there was a greater metabolic uniformity in tissues when grown in identical media than exists in tumors growing in the same host, or in hosts of the same age and genetic constitution. Thirdly, sarcoma cells when grown in culture retain the metabolic characteristics belonging to tumors.

The metabolic characters included in the observations were the respiratory and glycolytic rates, both aerobic and anaerobic. Also, the effects of glucose upon the respiratory rates and quotients were determined. It was found that sarcoma cells have a relatively greater rate of aerobic glycolysis than normal fibroblasts growing in plasma, and this gives us another character for the

malignant cell. The effect of glucose is to increase the respiratory rate of sarcoma cells, suggesting that sarcoma cells may oxidize glucose.

It may be added here that Dr. Lewis has prepared additional analytical reviews on the problem of malignant cells. One of these was presented last year as a Harvey Lecture. In this he collects the evidence supporting the thesis that malignant cells are permanently altered cells. As regards viruses, he concludes that though they produce tumor cells behaving like malignant cells, the cells which they produce are not to be regarded as permanently modified ones until it is sure that no virus is harbored in their neighborhood as the stimulus in their formation.

#### RENAL ELIMINATION OF HEMOGLOBIN

Using rabbits, Dr. I. Gersh has completed a series of experiments to determine the places of elimination of hemoglobin in the kidney. He finds that it occurs in the glomerulus as well as in the tubule. The animals were injected intravenously with a solution of carbon monoxide hemoglobin. The hemoglobin can be recognized microscopically by its color. Three groups of animals were compared, as follows: (1) Normal rabbits injected with hemoglobin, in which the glomerular space is filled at height of elimination. Later (about one hour) it disappears from this space. It is also in the cells of the proximal convolution in the form of granules. The loop of Henle shows a marked concentration of hemoglobin. (2) Dehydrated rabbits, with concentrated urine resulting in concentration of hemoglobin in the convoluted tubes and loop of Henle. (3) Low-pressure animals, in which the hemoglobin is found in the glomerular space as well as in the cells and lumen of the upper portion of the proximal convolution. Since the hemoglobin is present in the tubular cells and lumina in all three of these conditions, it becomes evident that it must be accounted for by tubular activity.

#### CENTRAL NERVOUS SYSTEM

##### THE MOTOR CORTEX

During the past five years Dr. Marion Hines has been studying the development and function of the cerebrum in fetal, newborn, and young macaques, with especial attention to the agranular frontal area, that is, the posterior part of the frontal lobe in which the internal layer of granular cells is wanting and in which is included the master field of the cortex known as the motor area and its related centers. Dr. Hines and those associated with her in these studies have been able to map out the frontal cortex with greater refinement than had heretofore been done, and to analyze the relation of the function of initiation of movement to the equally important function of inhibition of movement and of muscle tone.

Using macaques of different stages of development and of accurately known ages, the experiments included the determination of the confines of the motor cortex by electrical stimulation and a study of the character and refinements of response at different stages of maturity. It was found that the earliest appearance of the pyramidal type of movement occurred in a fetus of 135 days gestation age, and at this time there is a tendency for

the face, arm, and leg areas to be separated by cortex from which no movement can be elicited. In these younger stages the cortical points are unstable and easily fatigued as compared with the adult. Similarly, other factors in movement response, such as facilitation, reversal, deviation, and centripetal individuation, are at this time present but relatively undeveloped.

Supplementing her observations on electrical stimulation of the intact cortex, Dr. Hines studied the results of removal of various cortical areas of the frontal lobe, and thus obtained confirmation and additional evidence as to the cortical location of the elements of paralysis and spasticity as concerns voluntary movement. The line of division between the well-known areas 4 and 6 of Brodmann has been made more definite by Dr. Hines's experiments, and also the functional activities of these two important regions will now be better understood.

This work fits in with the results obtained by Dr. Tower by surgical division of the corticospinal tract at the pyramids. In two fetal monkeys whose frontal lobes had been explored electrically immediately after their removal by Cæsarian section, the pyramids were cut by Dr. Tower and their cortices reexplored, and in this way the unexpected result was obtained that the extrapyramidal inhibition develops before pyramidal initiation.

Furthermore, it was found that though movements could be definitely localized in the motor cortex, inhibition of tonic states and associated movements were not similarly localized. The inhibitors were found to be grouped physiologically. Those of flexor tone lie anteriorly to those of extensor tone and they affect arm and leg in a similar manner. Together they accomplish a reciprocal inhibition which facilitates voluntary movement. In agreement with Dr. Tower, Dr. Hines emphasizes the separation of the phenomena of spasticity from those of paralysis.

#### MOTOR AND INHIBITORY ACTION OF THE EXTRAPYRAMIDAL CORTEX

In previous reports I have referred to Dr. Tower's experiment of sectioning the pyramids (corticospinal tract) and the information that is thereby obtained on the complexity of this great motor tract. The operation is a difficult one, but the unmistakable information yielded by Dr. Tower's procedure more than compensates for the effort and skill required in its performance.

In a large series of cats Dr. Tower in the first place explored the frontal lobe cortex both for motor function and for inhibition phenomena which could be dissociated from motor function by differences in threshold or in distribution. One or both pyramids were then cut and the residual cortical responses were reexamined after various elapsed periods, representing extrapyramidal activities.

The results which she has obtained over a period of several years have been brought together by Dr. Tower in a detailed publication. Included in this is an analysis of the location and mechanism of the extrapyramidal inhibitory action of tone, that is, the inhibition of tonic contraction in the



skeletal musculature, particularly of the legs. Similarly there is reviewed the extrapyramidal inhibition of movement, that is, arrest or retardation of movement in contradistinction to mere cessation. Here are included rhythmic movements such as respiration, tail-wagging, and oscillations of the eye. A third section deals with extrapyramidal motor activity. It is found that in contrast with the simplicity of corticospinal action, extrapyramidal motor action is complex and unpredictable. It shows only with light anaesthesia and increases in complexity and variety with each lighter stage. It is likely to appear in fragmentary fashion, but these fragments are complex integrated movements; also, contrary to corticospinal action, the extrapyramidal motor response is slow to appear, increases gradually, and tends to outlast the stimulation as rhythmically repeating movement.

An effort was made to trace the extrapyramidal activities downward toward the cord. By successive ablations and stimulation of the cut surfaces at deeper levels it was found that the responses were equally strong under the cortex, in the central white matter, and into the internal capsule and hypothalamic region. Removing the caudate nucleus made no difference. On reaching the midbrain, well-integrated movements were more difficult to obtain, though elements primary to their performance could still be demonstrated and notably in the tegmentum. Apparently as the hindbrain is reached, the peduncles, pons, and cerebellum participate in this extrapyramidal action. At the medullary levels the fibers have already crossed and the lateral part of the tegmentum appears to be the principal path of conduction.

In her summary of the organization of pyramidal and extrapyramidal activities, Dr. Tower points out that the motor function is organized in two major parts: (1) the corticospinal tract, which operates on the various terminal segmental levels, and (2) the extrapyramidal activities, which operate indirectly through the medium of lower brain-stem activities. As for inhibitory functions of the cortex, these are mainly extrapyramidal and they apparently act on the brain-stem motor mechanisms. In the corticospinal tract inhibition is a function of the intrinsic cord mechanism, for there is no independent inhibitory action in the tract itself. Thus the cortex acts upon these mechanisms at four principal levels. The most distal is the segmental level, which is the final site for integration of movement. Above this is the brain-stem motor mechanism for reintegration and for introduction of the elements of posture. This projects down on the segmental level. The thalamic level constitutes a motor mechanism for further integration and for pattern formation. It projects to the brain-stem mechanism but not down to the segmental level. Finally there is the cortex, the highest level of integration, and this projects down upon each of the three lower levels. It is able to activate or inhibit activity throughout the whole axis, from the source to the segmental level. The anaesthesia and the very disturbing circumstances of the experiment doubtless interfere with anything approaching a complete picture of the total functions of the cerebral cortex, but it is felt that from Dr. Tower's work we have obtained a reliable outline of some of the simpler brain mechanisms.

## THE ISOLATED LUMBOSACRAL SPINAL CORD

In some experiments contrived to determine the fate of functionally isolated nervous tissue, Dr. S. S. Tower has been able to obtain some side-lights on the nature of trophic control. It was found that in young growing animals the lumbar enlargement of the cord could be isolated from incoming stimuli with relative impunity. All the posterior roots of that region were cut and the cord transected above and below the enlargement. Such animals were kept alive up to six months. When this was done, the structures having their nerve supply from this region lost all ordinary activities, including muscle tone. Muscle contractions of definite pattern occurred from time to time apparently activated by conditions within the isolated cord, and cannot be regarded as spontaneous nerve-cell activity. The same kind of contractions could also be produced by direct stimulation of the cord. Evidently inherent nervous activity is not a characteristic of the mammalian spinal cord. At the end of the experiment the isolated spinal cords, the root ganglia, and the peripheral nerves were prepared for histological examination. It was found that they were composed in large part of healthy nerve cells and fibers. Moreover, the cells and fibers had grown in size and there was evidence of tissue repair. Thus nervous tissues can retain their integrity in the absence of nervous activity. It was found, however, that non-nervous tissues are dependent for their trophic control both upon the physical integrity of their innervation and upon nervous activity. But this does not necessarily set up special trophic nerves to care for this responsibility.

## CORTICAL FUNCTIONS OF THE KANGAROO RAT

The motor cortex of the kangaroo rat, *Dipodomys*, has been studied by Dr. W. L. Straus Jr. as representing a form in which the locomotor apparatus has undergone extreme specialization. This is the same form whose structural and functional characters were referred to in a previous report (Year Book No. 32). Having a sufficient number of specimens available, Dr. Straus has been able to demonstrate that the hindlimbs and tail of this animal are not represented in the motor cortex. Instead they appear to be represented in a center in the subthalamie region and their movement could be elicited by stimulation of the tegmentum of the midbrain.

The kangaroo rat, however, has a motor cortex, as Dr. Straus demonstrated both by stimulation and by cyto-architectural evidences. It forms a narrow strip spreading from the frontal pole backward along the dorso-lateral surface of the hemisphere and well above the rhinal fissure. On stimulation of this area there were responses involving the face, head, and forelimbs. The elicited responses included movements of the vibrissæ and upper lip, closure of the eye, and movements of the foreleg. The vibrissæ movements were usually bilateral but they were also seen occurring only on the same or opposite side. The eye closure was always restricted to the opposite side. The forelimb responses were varied. At times they were confined to one segment of the limb, but commonly they involved two or



more segments. If but one segment, it was usually the upper or proximal segment. A common combination was upper arm protraction, forearm flexion, and rhythmic clawing of the fingers, together suggesting feeding movements.

The most regularly responsive cortex was found to be roughly divided into four parts (areas A, B, C, and D). The first of these is concerned exclusively with the face; the second also controls the face but has some leg representation; the third is largely forelimb, though the face is still represented, and the fourth is particularly concerned with the forelimb. By means of serial sections through these regions they could be recognized microscopically as a motor area and comparable to areas 4 and 6 of Brodmann's well-known map. The alignment of the body parts in these four areas agrees with that seen in the bat and hedgehog described by Dr. E. Huber in his study of the phylogeny of the motor cortex and referred to in a previous Year Book (No. 32).

In one specimen Dr. Straus had the opportunity of studying the effect of decerebration, that is, transection of the midbrain. In this condition the animal exhibited periods of rigidity, alternating with intervals of relaxation or of progressive movements of the simpler type (diagonal). The posture of the forelimbs following decerebration departed from the usual reaction, such as seen in the cat and dog, by exhibiting flexor instead of extensor rigidity.

#### AN IMPROVED INSTRUMENT FOR ELECTRICAL STIMULATION

As greater precision became necessary in delimiting the motor cortex it was found that a large element of uncertainty was due to the electrical instruments in use for stimulation tests. Fortunately one of the students (Dr. John A. Myers) came to the anatomical laboratory equipped with a considerable training and experience in electrophysics. With his help it was found that the inductorium, the standard type of instrument used for stimulation by physiologists, has great disadvantages. Notable sources of inconstancy rested in the uncontrollable variations in the magnetic saturation of the iron core, variations in the vibrator frequency, and difficulties with burning and sticking contact points. Giving up the inductorium, Dr. Myers designed a new instrument consisting of a simple potentiometer circuit that can be operated directly from a 60-cycle, 115-volt lighting circuit and delivers a sine wave current whose strength and vibrations can be kept constant over a range of 0.02 to 10.0 volts. The current flowing through the instrument is very large as compared with the stimulating current and therefore does not vary during stimulation, and since the stimulating voltage is derived from the voltage drop along a resistance wire, it can be calibrated with great accuracy. Hereafter we shall know that any variations in our results must be attributed to the depth of the anaesthesia or to the peculiarities of the tissues of the individual animal and not to the frailties of our stimulator. Dr. Myers has prepared and published a detailed account of the construction of this apparatus so that the great advantages derived from its use will not be limited to Baltimore.

## STUDIES IN PHYSIOLOGY OF REPRODUCTION

## PHENOMENA RELATED TO OVULATION

The parallelism of the menstrual cycle of the macaque with that in women, pointed out by Dr. Corner, and the overwhelming evidence later obtained by Dr. Hartman on the occurrence of ovulation midway between the menstrual periods, have been outlined in previous reports. Also reference has been made to Dr. Hartman's discovery that ovulation in 75 per cent of the menstrual cycles in the macaque is accompanied by an intermenstrual bleeding, varying from a few red cells seen with the microscope to obvious bleeding. This work has led to a more careful review of these matters in the medical clinics. During the past year Dr. L. R. Wharton, a guest in this Laboratory, together with Dr. E. Henriksen, has made a study of ovulation as seen in operative cases. Their attention has been directed particularly to cases exhibiting periodic intermenstrual pain. Of 61 cases of this character, 30 were operated upon and an opportunity was had to inspect the pelvic organs. In none of them was there any evidence of any pathological process, nor was any explanation arrived at as to the cause of the pain. Such patients are fertile and bear healthy children. The pain is definitely associated with the ovaries and thus removal of the ovaries invariably eliminates its recurrence. This does not help much clinically because of the disadvantages of that procedure. The point of chief interest to the physiologist is that the pain is synchronous with ovulation, as has been convincingly shown by these investigators, and in such women we are informed as to their time of ovulation.

Additional records of ovulation in the macaque have been obtained by Dr. Hartman, confirming his earlier work and filling in his frequency curve of the ovulation day. Because of the discordance of the human records, where ovulation has been thought to occur at all stages of the cycle, Dr. Hartman has reviewed this evidence and concludes that the discrepancy is largely a result of faulty record. A better knowledge of the date of ovulation in women is of considerable clinical and social importance and it is expected that the invention of new tests and more careful study will reveal in women a cycle that will resemble the one which is now so well established in the monkey. As in the latter animal, individual variation reduces the phenomenon to a question of frequency or probable date of ovulation. Dr. Hartman advises the students of birth control as to the extent to which allowance must be made for this.

A note may be added here regarding an analysis by Dr. Hartman of the problem of fertilization of the hen's egg. Since the hen may continue to lay fertile eggs for several weeks after isolation from the male, it had been thought by some that fertilization of a whole clutch of growing oöcytes occurred within the ovary. The evidence is brought out by Dr. Hartman that retention of live sperm within the folds of the oviduct is sufficient to account for the above phenomenon. He also points out that as early as the second day after changing males, eggs are fertilized by sperm from the replacing male. He concludes that the hen's egg is not fertilized in the ovary.

Connected with the study of ovulation is the later fate of the follicle. The effort to determine the date of ovulation by the appearance of the succeeding corpus luteum has not been successful and has frequently led to misguided conclusions. Believing that an opportunity existed in the ma-

caque to correlate ovarian histology with ovarian function, at least more accurately than had previously been done, a cooperative effort has been made by Dr. G. W. Corner, Dr. G. W. Bartelmez, and Dr. C. G. Hartman toward that end. Pooling their abundant and accurately controlled material, they have advanced on the problem far enough to distinguish the normal from the abnormal. During the past year an account has been published by them of aberrant corpora lutea as found in the macaque. With the characteristics of the atypical structures known, a large source of confusion to students of reproduction will be eliminated. They find that the corpus luteum of pregnancy after the third week is distinguished by distinctness of the pattern of folding of its tissue, by the smallness of the granulosa lutein cells and absence of any cytoplasmic lipid inclusions, by the prominence of the pericellular network of capillaries, and finally by the distinct visibility of the theca interna cells.

The significance of these items must remain conjectural for the present. The authoritative character of their study is outstanding, as can always be expected where it happens that experienced investigators find it advantageous to cooperate toward a common goal, and particularly if the cooperation be so mutually generous as it was in this case.

#### MENSTRUATION

In a search for some extra-ovarian cause of menstruation, Dr. Hartman and Dr. W. M. Firor observed that in a monkey whose pituitary gland had been removed, there was no uterine bleeding after injections of the hormone estrin, which usually results in bleeding. This seemed to point to the pituitary as the source of a bleeding factor. It led to a series of experiments. In the first series of seven animals, the results were inconclusive because it was found that the pituitaries had not been completely removed and the animals bled after estrin like normal ones. One animal did not bleed and it was found that the posterior lobe was gone while the anterior was intact. This seemed to point to the posterior lobe and to pituitrin as the factor sought.

A second series was operated upon with the purpose of leaving the posterior lobe intact and removing the anterior lobe. In three monkeys the experimenters succeeded in removing the anterior lobe and leaving the posterior intact, but these also bled after injection of estrin. It was therefore evident that the anterior lobe cannot be regarded as the seat of the extra-ovarian factor. The posterior lobe has also been eliminated by the failure to produce menstrual bleeding by giving varying doses of pituitrin, even to the extent of continuous injection up to six hours. For the present therefore the pituitary gland is disposed of as the cause of menstruation.

In the report of last year, in describing Dr. Markee's important observations, it was pointed out that menstruation does not start as a general hyperæmia of the lining of the uterus with diffuse hemorrhage from its surface. Instead it consists of multiple minute hemorrhages, individually of brief duration, occurring at irregular intervals, the whole process, however, extending over a long time period. With characteristics so local in their distribution one would conclude that menstruation is not a hormone-controlled phenomenon. But the search for some extra-ovarian "cause" must go on.



PROLAN PREGNANCY TEST IN *Macaca mulatta*

It has been found by Dr. G. W. D. Hamlett that the pregnant macaque gives a typical "Friedman" reaction for a period of about one week, soon after implantation. Positive reactions were had during the period between the nineteenth and twenty-fifth days ovulation age. Other investigators had had negative results from the end of the first month to term. They had not started their tests early enough.

The transitory excretion of prolan in the urine of the macaque corresponds roughly to the period of maximum secretion in women. In women, however, after the characteristic decrease in its production there still remains throughout pregnancy a sufficient amount to give the typical reaction when injected into rabbits, namely, induction of ovulation. It becomes of great interest to know what phenomenon is responsible for this reaction during those few days in the macaque, and the expectation is that it will be explained by something concerned with placental activity.

## FACTORS UNDERLYING SEXUAL BEHAVIOR

Using nine female macaque monkeys, Dr. Josephine Ball has followed their sexual responsiveness over a period of two or three years for the purpose of determining in what way this element of behavior is altered following castration. Four of the animals had been tested through several normal menstrual cycles before the castration was performed. It was found that removal of the ovaries is followed by loss of sex interest, until, after varying periods of time, it is entirely gone. There remains, however, a slight tendency to periodicity. The injection of estrogenic hormone (Progynon B, Schering) raises sexual response to normal, but this requires smaller dosage if it is given at the correct monthly intervals.

In another series of observations Dr. Ball has studied sex behavior in three macaques which became pregnant during the course of observations. This gave an opportunity to correlate behavior with the anatomical and hormonal phenomena which were being studied in the same animals by other observers. Quantitative changes in sexual responsiveness were found to be correlated with endocrine changes and with the process of implantation. During the first month of pregnancy there is a tendency toward continuance of cyclic changes in behavior and vaginal desquamation. During the same time the trophoblastic shell of the ovum is parasitizing on the maternal epithelium and prolan is found in the urine. As villi are developed and the fetal circulation becomes established, prolan disappears from the urine and the cyclic return of heightened sexual responsiveness is discontinued.

Further correlations between sexual behavior and hormonal influences have been demonstrated by Dr. Ball in rats. It was found that castrated females could be kept at a low degree of receptivity by small daily doses of estrin, and when this was supplemented by luteinizing hormone, heat behavior could be brought on with less stimulation in 11 out of 15 cases tested. On the other hand, progesterin was found neither to increase nor to decrease receptivity in estrinized castrated rats. This of course may be a species charac-

teristic. The rat may be insensitive to progesterin in respect to behavior. When they are deprived of their hypophysis, female rats show no change in sex behavior with the administration of estrin, though castrated rats are thereby promptly brought into heat. This suggests that estrin works by way of the hypophysis. Certainly when supplemented by luteinizing hormone considerable stimulus results and most of the characteristics of heat behavior ensue.

Following an extensive experience in testing and rating the sexual excitability of the female rat, Dr. Ball has prepared her records and tabulations for publication along with an analytical treatment of the results. With improvements in the procedure a high reliability coefficient has been obtained. With these tests Dr. Ball has added to our knowledge of the diurnal distributions of the beginning, peak, and end of the estrous period and the time of occurrence of various degrees of excitability. Also her tabulations reveal the time relationship between vaginal smears and sex behavior. Because of the existing need of adequate quantitative methods of measuring sexual excitability this publication will have immediate value to other workers. Dr. Ball's studies have been carried on in collaboration with Dr. Adolf Meyer and have been aided by the Committee for Research on Problems of Sex of the National Research Council.

## ANATOMICAL AND COMPARATIVE ANATOMICAL STUDIES

### DATA ON COMPARATIVE GROWTH IN PRIMATES

The observations and measurements on fetal macaque material made by Dr. A. H. Schultz and referred to in an earlier part of this report have enabled him to compare some of the main growth features of three representative primates, namely, macaque, chimpanzee, and man. Their growth is divided into that of intra-uterine life and postnatal life, the completion of the latter being marked by the time of completion of permanent dentition. From such data one finds that the duration of intra-uterine life, in percentage of the total duration of growth, is: for man 3.5 per cent, for chimpanzee 5.2 per cent, and for macaque 6.2 per cent. Similarly the average daily increase of weight could be calculated in percentage of weight at the completion of the growth period, both for prenatal life and postnatal life.

From such data Dr. Schultz finds that the newborn macaque is more advanced in development than newborn man. As for the chimpanzee, the data are not so abundant as those for the macaque and man. They indicate, however, that the chimpanzee lies between macaque and man in his degree of development at birth. Already at the 132d day, 34 days before birth, the macaque has reached the stage of ossification typical for newborn man, and at birth he has many more ossification centers in his limbs than appear in newborn man. Furthermore, the fontanelles of the macaque, and of the great apes also, are nearly or entirely closed at birth, and the first teeth erupt in the macaque from 0 to 5 weeks after birth, whereas in man they do not erupt before the 26th week. In comparison with the chimpanzee and macaque it is thus found that man is born both prematurely and immaturely.



## BODY PROPORTIONS IN FETAL AND ADULT GORILLAS AND CHIMPANZEES

In the course of growth of any animal its body proportions exhibit great alteration and the student of phylogeny attaches significance to the ontogenetic shifting of such relationships. It is therefore of much interest to determine the growth changes among the higher primates and it is expected that better acquaintance with them will enable us to discern more clearly the original primary characters from newly acquired specializations. Owing to the scarcity of anthropoid fetal material it has heretofore been impossible to obtain this information. Dr. A. H. Schultz, however, through cooperation of other investigators and institutions has been able to gather measurements in varying degrees of completeness on 12 chimpanzee fetuses and 8 gorilla fetuses. The measurements for the most part were made by one person, namely, himself. These measurements have been tabulated and compared with corresponding measurements of adult male and female chimpanzees. The measurements included in Dr. Schultz's study include the proportion of the chest circumference to trunk length, the relative shoulder width and the relative pelvic width, nine proportions involving the limbs, and for the head, the relative head size, relative facial height, proportional cranial height to facial height, the interocular index, and the ear size compared with profile area of the entire head. In following the changes in these various proportions with growth, Dr. Schultz has provided us with clearly defined examples of how phylogenetic specializations can be traced back to alterations in proportion incident to growth.

## A STUDY OF MAN'S RELATIONSHIP TO THE ANTHROPOID APES

Adhering rigidly to standard anthropological methods, an important analysis has been made by Dr. A. H. Schultz of the evidence as to man's phylogenetic position with reference to the manlike apes, basing his conclusions on likenesses and points of greater or lesser specialization. Perhaps at some future time a way will be found to apply other and better methods to such an analysis than the present anthropological ones, which are limited to characteristics that can be converted into numerical expression. The conclusions which Dr. Schultz arrives at are based on 58 characters. When it is realized that man's characteristics are almost infinite, one must grant that the ones Dr. Schultz was able to make practical use of are to be regarded as sample items only. Furthermore, they are confined almost exclusively to structural details. Thus far functional phenomena have played small part in taxonomy, although it is recognized that structure and function are essentially inseparable. One wonders if greater use of physiological characters would not widely extend the basis on which the answers to these questions must rest.

In studying the history of art a general consensus of opinion has been arrived at as to superiorities and inferiorities of the great paintings and their interrelations. Such conclusions are based on the characteristics of these masterpieces. The characters that are accepted as important in a painting are rarely ones that can be reduced to numerical expression, but they are none the less real and they are certainly concerned with physical

substances such as paint and other materials—and until recent times, with proportion and symmetry. In music and literature we also make comparisons and discover relationships without resort to mathematics. However, in art, music, and literature it is not customary to segregate the different va-

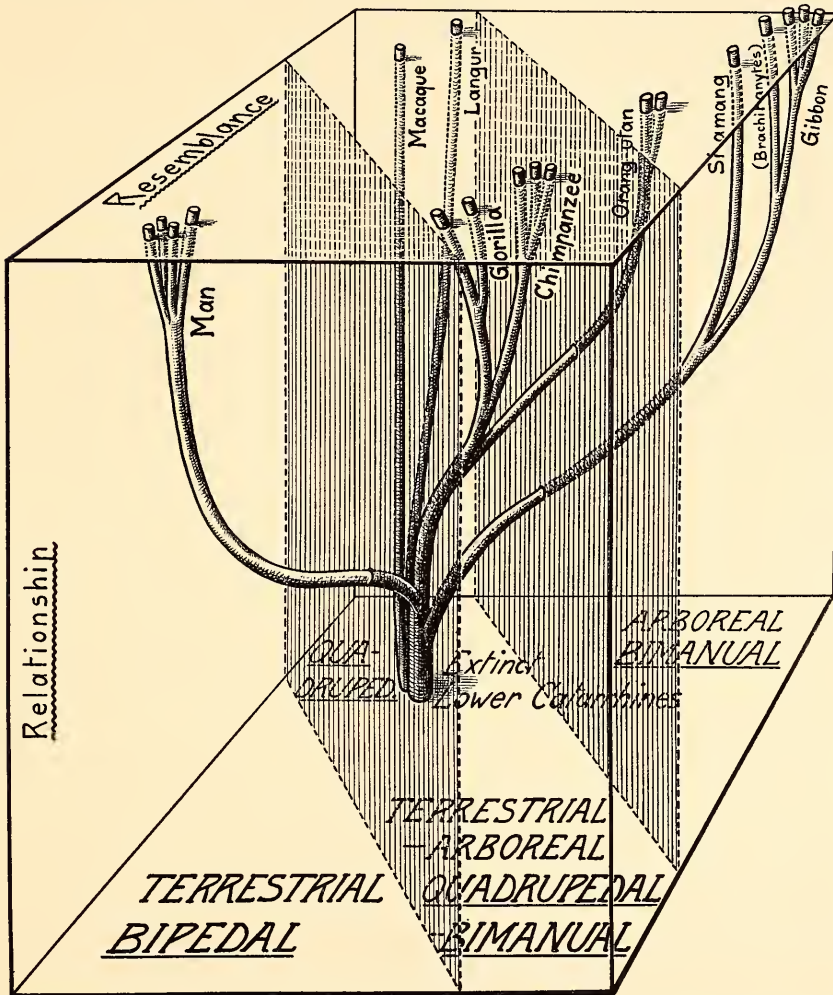


FIG. 1—In this drawing Dr. Schultz has departed from the customary two-dimensional genealogical tree and by the third dimension represents the degree of resemblance as well as genetic relationship of these higher catarrhine primates. The habitats and mode of locomotion (underlined) are inscribed on the base of the drawing.

rieties into genera and species, whether we regard the said paintings, musical compositions, or literary productions as comparable objective things or whether we analyze them as comparable behavioral records of human beings,

and therefore there seems to have been no temptation in these domains to design genealogical trees. But it is otherwise with the objects Dr. Schultz has been studying and the methods he has used have yielded convincing results.

As for man's taxonomic position, there is little dispute as to his close relationship to the great apes and the gibbon and siamang, man together with them constituting the higher catarrhine group of anthropoids. There has been, however, some difference of opinion as to whether the phylogenetic branch for man originated before, at the same time as, or after the branches for the great apes began to diverge. Dr. Schultz's studies have led him to the conclusions expressed in the accompanying figure 1.

Among higher primates as a whole there is found a marked plasticity and tendency to specialization and evolutionary trends. Since these trends are largely in the same direction in all of them, a natural group is created. Of the sixty characters studied by Dr. Schultz, sixteen were, among the higher primates, in divergent directions. All the others were found to have a definite common trend in all the anthropoid apes and man. The following striking examples may be given. Dr. Schultz shows that, as contrasted with lower catarrhines, all higher primates tend toward a prolongation of the duration of pregnancy and the total period of postnatal growth, gradual disappearance of ischial tuberosities, a varying tendency for fusion of two of the wrist bones, late fusion of the nasal bones, reductions in the number of vertebræ and especially the thoracolumbar and caudal vertebræ, increases in the number of sacral vertebræ, increases in the relative length of the neck, decreases in the relative length of the lumbar spine which bring the thorax nearer to the pelvis, increase in stoutness of trunk, increase in width of shoulders, chest, and hips, marked lengthening of the limbs, lengthening of hand and thumb in proportion to body size, increases in relative size of head and volume of brain, widening of the sternum and the iliac portion of the pelvis, and lengthening of the tarsus. From such examples of identical trends Dr. Schultz makes clear that this group is endowed with the same tendencies and from one common ancestral source.

As to the phylogenetic relationships between the members of the group Dr. Schultz concludes that man, and not much later the Hylobatidæ, began to develop as an independent evolutionary branch considerably before the orang had diverged from the common stem of the great apes. In supporting this view it is pointed out that genetic relationships must not be sought in isolated characters, but must be derived from as numerous and diverse characters as possible. Thus man is distinguished from the great apes by a particular combination of many primitive and many highly specialized characters. If the characters are so listed, it is found that man is twice as frequently "less specialized" as he is "more specialized," as compared with one or another anthropoid ape. At the same time he exhibits many more extreme specializations than any of the group.

Based on a list of 57 characters, man resembles the gorilla most closely (23 characters) and the gibbon next (15 characters). The gorilla on the other hand resembles the chimpanzee most closely (30 characters), and vice versa. These two African apes stand close together. The orang resembles most



closely the chimpanzee (19 characters) but also closely resembles the gibbon (17 characters). Finally, the gibbon resembles most closely the orang (23 characters), next the chimpanzee (15 characters), and man (11 characters). From such a study of resemblances it becomes obvious that the two African apes stand very close together, so much so that the question arises as to whether they should not be put in the same genus. They became phylogenetically divided after an independent branch for the orang-utan had appeared. Furthermore, the orang-utan must have diverged from the ancestral stock after the separation of the branch for man, inasmuch as the average differences between the three great apes are smaller than those between any of the latter and man.

The exact place of separation of an independent phylogenetic line for man can only be determined by such an unbiased survey of the relative degrees of resemblance between all the different higher primates, and in doing this one must distinguish as to whether the respective character represents the retention of a primitive condition or is a high specialization of itself. Also quantitative characters, such as relative size or frequency of a structure, are to be distinguished from qualitative ones, such as the presence or absence of a structure, though the latter may gradually result from the former. It may be that the final answer to the question of man's genetic relationship to his simian kin must bide the time until he can be treated in his entirety.

#### RACIAL DIFFERENCES IN WHITE AND NEGRO FETUSES

In connection with Dr. Schultz's phylogenetic evaluation of man, a note should be added regarding the study of Dr. R. Hauschild made in Professor Eugen Fischer's laboratory in Dahlem, Germany. The object of the study was to determine whether or not racial differences existed in primordial crania as early as the third fetal month. We cooperated in this investigation to the extent of lending serial sections of Negro fetuses of this age. Dr. Hauschild reconstructed the fetal skulls and compared them with similar reconstructions of European white fetuses. His observations show that already at that time the cranium exhibits morphological characteristics which distinguish the Negro from the white.

#### THE WOOLLY MONKEY

The opportunity of studying the anatomy of this relatively rare animal has led to two contributions to the field of comparative anatomy. One of these, by Dr. W. L. Straus Jr., concerns the presence of a cervical rib. This anomaly is occasionally seen in human material, about 2 per cent. Otherwise it has been recorded in but two other primates, *Perodicticus* and *Gorilla*. Dr. Straus suggests that the extreme rarity of cervical ribs in primates other than man may be attributed to the loss of the ribs during the process of dissection, which can easily happen owing to their small size.

The other contribution to which I referred is a study of the arteries of the hind and forelimb made by Mr. F. A. Bang with the assistance of Dr. DeGaris. Among the conspicuous features of the arterial pattern of this animal are: the high bifurcation of the brachial artery into the radial and ulnar arteries, rudimentary obturator and medial circumflex arteries which are

supplanted by branches of the deep femoral artery, and an extensive development of the saphenous artery which trespasses into the territories of the anterior and posterior tibial arteries. Doubtless these departures from the primate pattern afford a more efficient blood supply for limbs of this character.

#### SPINAL ACCESSORY NERVE

The spinal accessory nerve is one which possesses many obscurities for the comparative anatomist, but to the mammalian embryologist it appears simple and unequivocal. The embryologist sees it only as a specialization and caudal extension of the vagus complex, serving a muscle mass derived from the branchial region and keeping quite aloof from the occipital myotome system. The comparative anatomist in dissecting various animals finds its fibers running in complicated and various pathways according as the animals have long flexible necks or short unspecialized ones. Dr. W. L. Straus Jr. and Professor A. B. Howell have reinvestigated this nerve both from the standpoint of its origin and central connections and from the standpoint of the field of musculature to which its peripheral fibers are distributed. They brought to the task a well-grounded acquaintance with the comparative anatomy of the muscles of the neck and shoulder region, and with this they have combined a careful study of the neural anatomy of the spinal accessory nerve and its central connections. To some extent it was possible to supplement their anatomical observations with functional tests. Thus they were able to settle some of the points by electrical stimulation of the fibers and by that means demonstrate the muscle innervation. Using dogs, they stimulated the central and peripheral stumps of the sectioned cervical nerves (second, third, and fourth), and recorded the effect on the accessory field of musculature.

Their conclusions support the viewpoint of the embryologist. They find the spinal accessory nerve to be a derivative of the vagus complex, and hence of visceral origin. Its motor nucleus is derived from the dorsal motor nucleus of the vagus nerve and undergoes caudoventral migration. Its afferent fibers are carried in the tractus solitarius, which is a visceral sensory pathway.

Originally a mixed nerve, it has a tendency to lose its sensory cells by their migration to the dorsal roots of the adjacent cervical nerves. The motor fibers also tend to adopt the new and shorter spinal pathway, where they become ensheathed with the emerging cervical fibers. This reaches an extreme in long-necked ungulates, in which the spinal accessory, as a separate gross entity, tends to disappear.

#### INNERVATION OF THE HEART

The details of the finer structure of the sensory nerve plexus of the heart and routes through which its fibers reach the central nervous system have been hitherto but poorly understood. That territory of neuro-anatomy has awaited the development of a technique adequate for its study. By utilizing a suitable regulation of the methylene blue technique in the cat heart, it has been found by Mr. W. A. Nettleship that excellent preparations of the peripheral distribution of this intricate system with its nerve endings can be obtained and, by supplementing these observations with degeneration



induced in the different parts of this system following separate section of the three pathways by which it is connected with the higher nerve centers, this investigator has provided us with a relatively complete account of the sensory equipment of the heart.

The operative procedures necessary for determining the nerve connections of the cardiac plexuses consisted of the ablation of portions of the associated extrinsic nerve trunks and then recording the nerve degeneration which followed in those portions of the cardiac nerves, that is, in the epicardial network and the endocardial plexuses and endings, dependent on those several trunks. The operations separately carried out included bilateral removal of the spinal dorsal root ganglia, cutting both vagus nerves including both the sensory and motor parts, cutting both vagus nerves so that only the motor part is included, and removal of the stellate ganglion on both sides, thereby completely isolating the heart from the sympathetic chain.

In the above manner this investigator has clearly demonstrated the existence of an endocardial nerve plexus, which is non-myelinated though it has its origin in the heavy myelinated fibers of the epicardial plexus. The endocardial plexus terminates in nodal points and in simple endings beneath the ventricular endocardium and in somewhat more complicated ones similarly situated in the auricles. By studying the degeneration which followed cutting the extrinsic nerves it was demonstrated that the endocardial plexus and its endings, both of the ventricles and of the atria, are dependent on the sensory portion of the vagus nerve. The endocardial plexus of the apex of the ventricles and of the walls of the coronary arteries are, however, dependent on the dorsal root ganglia. Removal of the stellate ganglia resulted in fiber loss in the epicardial ventricular trunks and, of course, in the coronary arteries. Finally, it is interesting to add that the cardiac nerves undergo typical Wallerian degeneration and that its end stages are reached more rapidly following separation from the vagus nerve (sensory) than separation from the sympathetic chain (vasomotor). From the fact that the heart possesses a sensory plexus so complete as is shown by these observations, we must assume that this plexus plays an important rôle in cardiac function.

At this place a note may be added regarding an anomaly of the moderator band. Mr. B. M. Dobyns, working with Dr. DeGaris, has studied the occurrence in this band of a large artery, being a branch of the right coronary and extending to the opposite ventricular wall. The vascular supply of the moderator band is ordinarily merely sufficient for its own purposes. In this anomaly, which appears to be a rare one, we have a considerable current of blood flowing by this pathway to the opposite wall of the heart. This instance occurred in a beef heart but it is not peculiar to that species.

#### INNERVATION OF THE PELVIC ORGANS

During the past few years Dr. L. R. Wharton, as a guest of this Laboratory, has been developing a technique with which to determine the fiber connections of the intricate nerve plexuses that supply the abdominal organs. He has succeeded in this and is now able to combine such features as fixation and selective staining of the tissues, and sufficient transparency and elasticity to allow microdissection. Their transparency also makes these specimens

suitable for photographic record, and, finally, they can be prepared as permanent mounts.

Reference to Dr. Wharton's studies on the innervation of the ureter was made in a previous Year Book (No. 32). During the past year he has completed a study of the innervation of the female reproductive organs of the macaque, in which he utilized his improved microanalytical methods. He found that the sacral and sympathetic elements could be accurately separated and that individually they could be reached surgically. This makes possible the severing of the nerve supply to the uterus, tubes, and vagina without the serious complication of also disturbing the innervation of the rectum and bladder. In other words, Dr. Wharton has provided us with a way to the study of the neural physiology of these organs. His own study was directed chiefly to the innervation of the ovary.

#### THE MACAQUE CERVIX

Comparing his extensive records obtained in a long clinical experience, Dr. R. L. Dickinson has been able to show how closely the macaque cervix resembles the appearances commonly met with in women; cooperating with Dr. Hartman, records of the color, consistency, and form of the cervix were made in thirty adult female specimens. It was found that the difference in form and pathologic behavior between the vaginal portion of the cervix of the macaque and that of woman is practically limited to that of size, differing about four-tenths in diameter. The character of the invagination, types of laceration, inflammatory phenomena, erosions, secretions, vascularity, and infantilism and asymmetries are more or less the same in both. The macaque was found to set itself off from the human in three points, namely, a greater dilatability of the lower cervical canal, presence of vaginal rugæ covering the anterior lip or in some cases both cervical lips, and the adhesion of the seminal plug to a circular rim of the projecting cervix.

Other than its contribution to comparative anatomy, this study of Dr. Dickinson and Dr. Hartman may have its greatest service in calling attention to the possibility of using the macaque as an experimental animal in studying human problems of the cervix.

#### OVARIAN ADHESIONS

In the course of his experiments on monkeys and opossums Dr. C. G. Hartman has seen the living ovaries *in situ* of a great many specimens. Occasionally in these laparotomies, in about 2 per cent of the animals examined, he has found slender adhesions connecting the ovary with the omentum. To determine their significance the ovaries were sectioned and studied microscopically. It was found that the adhesion is connected with the corpus albicans. The adhesions were examined in earlier and older stages and it was found that apparently their strands arise by cellular organization of the material issuing from the ruptured follicle. The liquor folliculi of which this material consists tends to be very viscous and tenacious, so much so that it can be drawn out into a thread twelve inches long. The full significance of this phenomenon must await further experience.

## THE WHALE HYPOPHYSIS

In a previous report (Year Book No. 28) an account was given of the structure of the cetacean hypophysis based on observations made by Dr. Wislocki on porpoise material from Cape Hatteras. At that time it was shown that the processus infundibuli is separated from the buccal portion of the hypophysis and that the pars intermedia is completely lacking. That the two components of the hypophysis could thus be separated and their active principles tested pharmacologically interested Dr. E. M. K. Geiling, who carried the research to larger whales and confirmed the absence of a pars intermedia and the complete separation of the anterior and posterior lobes. Since initiating this work these two investigators have both left Baltimore, but have continued in cooperation a histological study of this interesting material on a much larger and more diversified series of specimens. Coming from the same source is the whale material that is being reported from this Laboratory by Dr. Walmsley.

## MORPHOGENESIS OF THE SHOULDER GIRDLE

In a previous report I referred to the reinvestigation of the problem of limb development undertaken by Professor A. Brazier Howell (Year Book No. 33). In this study he has obtained a broader view of the significance and morphogenesis of the shoulder region by paying simultaneous regard to the muscular, neural, and skeletal systems. He has also included the early stages in the embryo, which present these structures in simpler form, and of course he has paid due attention to the comparative anatomical correspondences. Mr. Howell's extensive anatomical experience and aptitude peculiarly fitted him for this important undertaking. Already the first three parts—introduction, fishes, and amphibia—have been completed and published, and during the past year two more parts have been completed, reptiles and monotremes.

In their shoulder architecture he does not find the monotremes in any way leading to the mammalian condition. The shoulder here is to be regarded as a specialization of the reptilian type, reaching its highest development and terminating in this group. It is an example of one of those blind ends which so frequently complicate phylogeny with respect to the development of organs and body parts. Mr. Howell's observations make it obvious that monotremes, as far as their shoulder goes, though coming from reptilian ancestors, were not derived from those reptilian forms that gave origin to the primitive mammals.

As a representative of the reptilian "stage" Mr. Howell made large use of *Iguana*. He found this form well suited for the study of nerve-muscle action. Particular interest lay in the innervation of the accessory field, where it was found that in some animals all the motor fibers to the accessory field of musculature are carried by the accessory nerve, while in others a portion of these fibers follow a spinal pathway. They have thus begun to adopt the shorter route. The brachial plexus was tested under electrical stimulation, both peripherally and intradurally. Motor responses to stimulation of the peripheral stumps, and also to stimulation of the central stumps, yielded the information on the zone of control at the different spinal levels and the extent and



character of afferent regulation which was necessary for the interpretation of the structures concerned.

#### MUSCULATURE OF THE FORELIMB AND FOOT

In a study of the musculature of the forearm and hand of *Ornithorhynchus* Mr. Brazier Howell further emphasizes the fact that the musculature in this peculiar order is so extremely specialized that it cannot be used for illustrating early steps in the phylogeny of mammalian muscles. It is not so much a primitive mammal as a mammal-like offshoot from the reptiles, that is, if our criteria are the muscles. The conformation and arrangement of most of the forearm are notably different from the general mammalian plan.

In connection with his interest in the limb structure of *Ornithorhynchus* Mr. Howell has turned his attention to its swimming mechanism and has shown that though its shoulder girdle and forelimb were originally very poorly designed for swimming, it has undergone unique modifications which adapt it fairly well to the aquatic requirements which confront it. This is brought about both by adaptations of its joints and by the projection of bony processes which, correlated with minor alterations in its musculature, provide efficient rotation of the humerus, on which it chiefly relies for speed in swimming. This peculiar humerus of the monotremes can undergo pure rotation through an arc of 135 degrees. The platypus swims by alternate thrusts of the forefeet. The skin of the paw is projected as a flap beyond the nails and so by expansion provides efficient purchase for propelling the animal. When the forelimb is thrust forward this integumental paddle folds back against the palm, thereby reducing the water resistance.

#### COMPARATIVE ANATOMY OF THE FORELIMB MUSCLES

The comparative myology of the forelimb has been studied by Mr. B. Campbell in the hippopotamus, pig, and tapir. These animals exhibit interesting muscle specializations, particularly in their forelimb, adapting them to their common type of locomotion. The movements of the scapula being largely in one plane, the extrinsic muscles of the shoulder are simplified to two groups, those tending to rotate the limb forward and those rotating it backward. Similarly, the humerus being limited largely to a single parasagittal plane, its acromial elements are markedly reduced. One of the most marked muscular specializations in these forms occurs in the m. supraspinatus, which becomes an independent extensor muscle. Fewer adaptations are found in the thigh musculature. The most conspicuous feature of the hands and feet is of course the conversion of muscles into supporting ligaments. Between this group of closely related ungulates and those ungulates with unpaired digits (perissodactyls) there are close similarities in these various respects, and it is pointed out by Mr. Campbell that their similarities are to be considered as parallelism.

A note may be added here regarding Mr. Campbell's observations of the foot musculature of some of the oriental races of man (Australian, Hawaiian, and Chinese). Though such material has been rather inaccessible to western investigators, Mr. Campbell was able to obtain enough for his dissections and has therefrom provided us with a survey which is important from a racial

standpoint and for comparison with American Negroes and whites. The details of the muscle insertions and muscle forms outlined by him will not be entered upon. Those having need for the data are referred to Mr. Campbell's publication which is listed in the bibliography accompanying this report.

#### PHYLOGENETIC ARRANGEMENT OF THE MUSCULAR SYSTEM

An interesting analysis of the arrangement of muscle groups has been made by Professor Howell. His study is carried out with particular reference to man and is an attempt to substitute a phylogenetic basis for the regional or topographical one in general use. In his analysis practically the entire striated muscular system is studied and classified.

First of all he separates the branchiomic muscularity from that derived from myotomes, and in this he will have the cordial support of the embryologists. The branchiomic muscles are grouped for convenience according to their respective innervation, but in doing this Mr. Howell does not assume that the gills are the final and sole directing influence of the entire head region. He takes an intermediate position between the gill-worshippers and the gill-belittlers.

Muscles derived from the myotome series are divided by Professor Howell into dorsal and ventral components. From the latter all the trunk muscles are derived, excepting those belonging to the erector spinæ system and to the extremities. The muscles of the extremities are divided secondarily into dorsal and ventral groups and also into special groups about the shoulder joint and the elbow and wrist of the forelimb. Similarly, the hindlimb is divided in respect to the muscular groups about the hip and the muscles of the leg and foot. The extrinsic muscles of the eye, like the trunk muscles, are regarded as derivatives of the dorsal myotome components. If the dissecting-room congregations can be brought to accept Professor Howell's way of grouping the muscles it may simplify their task, but it will not reduce the number nor the variety in the characteristics of the muscles with which they must become acquainted. The examination room at Leiden will continue to carry over its doorway the inscription *Hic sudavit sed non frustra*.



DEPARTMENT OF GENETICS <sup>1</sup>

A. F. BLAKESLEE, DIRECTOR

## DATURA INVESTIGATIONS

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## THE SPECIES PROBLEM

Study of the chromosomal differences among the herbaceous species of the genus *Datura* has been continued. The method employed involves matching up the ends of chromosomes from the various species with the chromosomes of the standard Line 1 race of *D. stramonium*. This procedure necessitates getting the chromosomes to be tested into a hybrid alongside those of Line 1. Unfortunately not all species will hybridize with *D. stramonium* and it is necessary, in consequence, to carry out the program by an indirect method through the use of intermediary or "bridging" species. The method requires considerable time and labor at best and the chances are slight of securing a viable hybrid in many of the species combinations. In certain cases several hundred pollinations have been made before a single successful hybridization has been secured.

Despite the tedium involved in the species program it is possible to report considerable progress during the past year in that two new species, *D. pruinosa* and *D. innoxia*, have had their chromosomes brought into direct contact with those from standard Line 1 of *D. stramonium*. *D. stramonium* will not cross directly with *D. pruinosa*, but will cross, though with difficulty, with *D. leichhardtii*. An attempt was accordingly made to obtain a race that would be like *D. leichhardtii* so far as crossability is concerned, while retaining the chromosomal end arrangement of *D. pruinosa*. An F<sub>1</sub> was first obtained between *D. leichhardtii* and *D. pruinosa*. By three times backcrossing to *D. leichhardtii* with retention of the chromosomes peculiar to *D. pruinosa*, a plant was secured which closely resembled *D. leichhardtii* and which showed the same two circles of 4 chromosomes characteristic of the F<sub>1</sub> generation. This plant was selfed and its offspring investigated cytologically in order to identify several which had 12 closed bivalents and hence would be homozygous either for the end arrangements of *D. leichhardtii* or for those of *D. pruinosa*. By backcrossing these homozygotes to *D. leichhardtii* and examining the chromosomes of the resulting hybrids one was found whose hybrids showed the same two circles characteristic of the original F<sub>1</sub> between *D. pruinosa* and *D. leichhardtii*. It was taken as the origin of the race desired, since it had the chromosomal end arrangements of *D. pruinosa* and the morphological appearance of *D. leichhardtii*. It was labeled "*D. pruinosa* chromosomes in *D. leichhardtii* matrix." In the meantime, there had been developed by continued backcrossing to *D. leichhardtii* a series of lines which had the chromosomal end arrangements of Line 1 *D. stramonium* in *D. leichhardtii* matrix. After several unsuccessful attempts, one of these Line 1 chromosome lines was finally crossed with the *D. pruinosa*

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chromosome race to give three hybrid plants in pedigree no. 3501682. They showed two circles of 4 chromosomes plus one circle of 6. From these configurations it is evident that 7 of the 12 chromosomes of *D. pruinosa* have end arrangements which are different from those of our standard Line 1 of *D. stramonium*. Our plan was to get the *D. pruinosa* chromosomes into *D. stramonium* by continued backcrossing to the latter species. Unfortunately it was found that the three plants of 3501682 would not hybridize with *D. stramonium*, although many attempts were made to cross them together. Crosses were finally obtained by using a race with chromosomes peculiar to Line 1 but with a considerable admixture of *D. leichhardtii* blood, which apparently aided crossability in this particular combination. The offspring of this cross consisted of seven plants which formed the pedigree culture no. 361060. They resembled *D. stramonium* slightly more in appearance than the three plants of 3501682 and it was hoped they would offer no difficulty to crossing directly with *D. stramonium*. All the plants of 361060 when used as males with *D. stramonium* failed to set good seeds. When 361060 was used as female, a few large seeds were formed which, however, have not yet been brought to germination. If this direct cross with *D. stramonium* is not successful, it will be necessary to use races with *D. stramonium* chromosomes which are intermediate in appearance between this species and *D. leichhardtii* before ultimately being able to backcross to the pure *D. stramonium* and to extract prime types which contain the chromosomes peculiar to *D. pruinosa*. The chromosomes in these extracted prime types can then be determined by studying the chromosomal attachments in hybrids with the various chromosomal testers already established in *D. stramonium*. In the process of working over to *D. stramonium*, the individuals of each backcross progeny must be examined cytologically to determine which chromosomes peculiar to *D. pruinosa* have been retained. Thus, of the seven plants in the progeny 361060, one plant had one of the two circles of 4; two plants had the other circle of 4; one had both the circles of 4; one had a circle of 4 plus the circle of 6; one had the two circles of 4 plus the circle of 6; and one plant had 12 bivalents. The procedure will be simpler in some ways if we succeed in getting backcrosses to Line 1 made on the plant with all the three configurations peculiar to the original  $F_1$ , but it should also be possible to backcross other plants of pedigree number 361060 and ultimately to isolate prime types from single configurations.

In a somewhat similar manner to that just described for *D. pruinosa* it has been possible to obtain a hybrid between *D. innoxia* and a race resembling *D. leichhardtii* in appearance, but with the end arrangements of our standard Line 1 *D. stramonium*. The hybrid contained one circle of 4 and one circle of 12 chromosomes, a fact which indicates that 8 chromosomes of *D. innoxia* have different end arrangements from those in *D. stramonium*. In these two cases we have determined how many chromosomes in a tester race of one species differ from those in our standard race in *D. stramonium*. To determine which the chromosomes are that differ, it will be necessary to purify by further backcrossing and to obtain hybrids with the proper chromosomal tester races.

The labor and uncertainties involved in the program which has just been outlined are great, but we believe the effort required is justified, since it is giving information regarding the evolution of chromosomes, and the evolution of chromosomes, we believe, determines the evolution of species.

GEOGRAPHICAL DISTRIBUTION OF CHROMOSOMAL PRIME TYPES IN *Datura stramonium*

A summary has been prepared and is now in press regarding the distribution in nature of the different chromosomal races of *D. stramonium*. Data are presented on the distribution of chromosomal prime types (PT's) in 583 races (287 purples, 289 whites, and 7 races which were heterozygous for P and W) from 362 loci exclusive of 51 races from botanic gardens and commercial firms. Prime types found in nature consist exclusively of races produced by segmental interchange between nonhomologous chromosomes in terms of a standard race, PT 1. With the exception of two single races, only five prime types (PT's 1, 2, 3, 4, 7) have appeared in our collections. Some areas are represented by a single PT or PT association. Thus, all the races from eastern Europe, with the exception of one race from Russia, and all the races from Asia, with the exception of Japan, are white-flowered PT 2; all the races from Brazil are PT 1 and also have white flowers; all the races from Peru are PT 3 associated with PT 2. In some areas a mixture of types has been found, for example in southwestern Europe, the West Indies, and Central America. In the United States most of the races are purples and predominantly PT 1 with PT's 2, 4, and 7 occurring scattered within the eastern area. Whites are found more frequently among the PT 2's than among the PT 1's, a fact which suggests that PT 2 was introduced into this region as a white race from Europe or Africa, where white PT 2's are predominant. Prime type 3 has always been found associated with PT 2, which latter PT is the one most widely distributed. It is concluded that PT 3 probably arose in a PT 2 race. The two other species of the *stramonium* group, *D. quercifolia* and *D. ferox*, have been found within the range of the "Peruvian" PT 2-PT 3 race. Since the tester races of these two species both have the 4 chromosomes of PT 2 and PT 3, it is suggested that these two species are phylogenetically related to *D. stramonium* through PT 2 and 3. Prime type 2 chromosomes are found in the majority of the *Datura* species tested. Prime type 4 and PT 7, however, appear to be limited to *D. stramonium*.

Similar studies are being carried on regarding the distribution of prime types within the other species of the genus *Datura* as part of our program of study of the differences between species.

SYNTHESIZED NEW "SPECIES"

Two new pure-breeding types with extra chromosomal material have been synthesized since our last report. In each case we utilized the .1 fragment from PT 6 in which the 1·2 chromosome had become broken into a .2 half which was joined to the 11·12 chromosome and a .1 free fragment. In the first case the 2·15 chromosome from PT 45 was combined with the fragment already discussed to make the equivalent of a 1·2 chromosome with the .15 portion left over as excess material. Since this extra .15 material could be



carried through the pollen, it could be got into a plant in double dose. It was therefore possible to substitute the chromosomes  $\cdot 1$  and  $2\cdot 15$  for the  $1\cdot 2$  chromosome and to obtain a homozygous pure-breeding compensating type with 26 chromosomes which is similar in appearance to the 25-chromosome secondary type  $2n + 15\cdot 15$ , which also has two extra doses of the  $\cdot 15$  end of the  $15\cdot 16$  chromosome but which cannot breed true. The synthesis of this new type is an example of the way in which a secondary  $2n + 1$  type which reproduces itself in only about a quarter of its offspring may be replaced by its morphological equivalent in the form of a pure-breeding race.

In the second newly synthesized pure-breeder, the  $\cdot 1$  fragment of PT 6 was combined with the  $2\cdot^{12}$  fragment of PT 51 to compensate for the  $1\cdot 2$  chromosome which was eliminated. The type which was obtained is homozygous for the  $^{12}$  hump and forms thus a new kind of pure-breeder in which a chromosomal hump is in excess. It may prove useful in location of genes which are in or near the  $^{12}$  hump of the  $11\cdot 12^{12}$  chromosome.

#### "BUD SPORTS" DUE TO CHROMOSOME ELIMINATION

A relatively high proportion of our cultivated varieties of fruits and ornamental perennial plants have arisen as variant branches or so-called bud sports. In *Datura* bud sports due to chromosomal mutations have been relatively common. Those most frequent involve doubling of the whole chromosomal complement to produce a diploid branch on a haploid or a tetraploid branch on a diploid. Elimination of a single chromosome or a chromosome fragment is a not uncommon cause of bud sports. Chromosomal deficiencies are confined almost entirely to those which involve the  $1\cdot 2$  or the  $17\cdot 18$  chromosome. The condition is most striking in respect to the  $1\cdot 2$  chromosome. Nearly every season at least a single case is found in which the  $1\cdot 2$  chromosome is eliminated to form a  $2n - 1\cdot 2$  branch. The  $\cdot 1$  half of this chromosome seems to be chiefly responsible for the chromosomal elimination. In several cases a  $2n + 1\cdot 18$  plant has produced a  $2n$  branch by the elimination of the  $1\cdot 18$  chromosome, while no  $2n + 2\cdot 17$  plants have shown sectorial deficiencies. The  $1\cdot 1$  chromosome in the secondary  $2n + 1\cdot 1$  type is so frequently eliminated to produce  $2n$  branches that we have found it difficult to keep this type growing without its reverting to normal diploid. The complementary  $2n + 2\cdot 2$  secondary, of which larger numbers have been under observation, has only once been observed to have eliminated its  $2\cdot 2$  chromosome. It is concluded that the rate of chromosomal elimination in the formation of bud sports is different for different chromosomes and that, in the case of the  $1\cdot 2$  chromosome, it is the  $\cdot 1$  half which most strongly stimulates the elimination. The fact that no clear-cut cases of bud sports due to mutations of single genes have been identified in *Datura* leads to the presumption that in other forms in which bud sports have not been adequately analyzed chromosome and not gene mutations have played the major rôle in the phenomenon of sectorial variation.

#### MODIFIED HAPLOID TYPES

A complete series of the twelve possible primary  $2n + 1$  types, as well as a high proportion of the twelve primary  $4n + 1$  types, have been recorded for

*Datura*. A secondary  $1n + 7.7$  type has previously been reported. Another modified haploid has been determined to be a secondary  $1n + 15.15$  type and this spring a primary  $1n + 13.14$  type appeared in our cultures among the offspring of the secondary  $2n + 13.13$ . It is the first primary  $1n + 1$  type discovered in *Datura*.

#### THE GAMETOPHYTE OF TRIPLOIDS

Two phases of the study of the gametophyte have been brought to completion and summarized in two papers on chromosomal behavior in male and in female gametophytes respectively. The assortment of chromosomes in 1000 pollen mother cells at I meiotic division has shown a significant divergence from the calculated values which leads to an increase in frequencies of nuclei toward the  $1n$  and  $2n$  classes. Division observed in 500 pollen grains occurs regardless of the number of chromosomes which they contain. The mean size of dividing grains increases irregularly with the number of chromosomes, but the correlation between size of grain and chromosome number is not close. Abortion in pollen grains occurs at various stages of development after division is completed. The increase of  $1n$  gametes over expectation is due only to a slight extent to chromosome assortment and chromosome elimination. The abortion of pollen after division, the lack of germination of pollen grains, and the abnormal growth of pollen tubes are the main factors in eliminating cells of the gametophyte with extra chromosomes. Owing to all factors which select against cells with extra chromosomes, there are around 3000 times as many effective  $1n$  male gametes as random assortment of chromosomes and equal viability of the different chromosome classes would lead one to expect.

#### DOUBLING OF CHROMOSOMES INDUCED BY CHEMICAL TREATMENT

Among a number of chemicals used in an attempt to cause doubling of chromosomes, one so far, the alkaloid colchicine, has been found to be effective in bringing about changes in germinating seedlings of different species of *Datura* which indicate that doubling of chromosomes has been actually induced. Similar changes have been brought about by treating seeds of other genera during germination. Methods are being worked out that may enable one to cause doubling of chromosomes in buds of adult plants. If, as appears likely, we have hit upon a method of doubling chromosomes at will, the plant breeder will be able to work with greater precision in his efforts to control the evolution of economic forms, both of plants propagated by vegetative methods and of those reproduced by seed. For example, it should be possible, starting with a sterile hybrid, to synthesize a pure-breeding double diploid which would have hybrid vigor and the desirable characteristics brought about by doubling the chromosome number. Doubling the number of chromosomes would give enlarged flowers and fruits to the horticulturalist. The tetraploid or  $4n$  condition is the starting point for a wide range of extra-chromosomal types. A  $4n$  plant crossed with a normal  $2n$  individual produces a  $3n$  the offspring of which, in *Datura* at least, include all the possible primary  $2n + 1$  types as well as double trisomic  $2n + 1 + 1$  types. Tetraploidy and presence of unbalanced extra-chromosomes



are known to have been factors in the origin of a large proportion of our most desirable varieties of fruits and flowers. In addition to increase in size of organs of the plant, tetraploidy has changed a self-sterile to a self-fertile form, a dioecious to a hermaphroditic race, an annual to a perennial, and has increased hardiness. The ability to induce chromosome doubling therefore is of importance to practical as well as to theoretical genetics.

### STUDIES IN TASTE SENSITIVITY

During the past summer our studies on taste sensitivity have been continued with the assistance of Dr. Margaret B. Erb, and threshold determinations have been obtained for a number of different substances. Of especial interest were the taste reactions to the sugar mannose, for which two different tastes are reported, sweet and bitter. The concentration at which 62 subjects could detect the sweet in single tests ranged from 1:5000 to 1:4.9. The range for the bitter was 1:2500 to 1:2.4. Thirty subjects detected the sweet first, 24 the bitter first, and 8 detected both sweet and bitter together. If a concentration of 1:156.25 had been used alone, 26 would have reported no taste, 20 sweet, 12 bitter, and 4 both sweet and bitter; of the latter, 2 would have perceived sweet before the bitter taste and 2 would have perceived the bitter first. With this information it was possible to make up tabloids containing 5 mg. mannose, which to some of a group are tasteless, to others sweet, to others bitter. These tabloids were used in a successful demonstration of the differences between people in their taste reactions this last April at a meeting of the American Philosophical Society.

The soda-fountain straw method of testing taste acuity for phenyl-thiocarbamide (P. T. C.) was used with the same 27 subjects for three consecutive years, one test being recorded for each year. In making up test solutions, a factor of 2 was used so that each concentration tested was twice as strong as that previously given. The least acute record was detection of the taste at a concentration of 1:312.5 (a saturated solution), while the most acute record was a concentration of 1:2,560,000. The former solution is over 8000 times as concentrated as the latter. One subject had a record the first year of 1:320,000 and the last two years had records of 1:625. This is an extreme range of 9 grades with the most concentrated solution 512 times as strong as the least concentrated one. Two of the subjects had the same records for the three years, 5 had a deviation of 1 grade and 10 had a deviation of 2 grades between their records. Thus, the records of over half of the subjects showed deviations of not over 2 grades for the three years. The data show that tests for taste acuity made in different years give records the majority of which vary within a limited range.

Since some of the subjects have shown considerable variation in their taste thresholds from time to time, it was thought that environmental factors might have an effect upon the acuity of taste. Attempts were therefore made to alter the internal environment in various ways such as by the administration of daily dosages of 20 gm. of sodium bicarbonate and of 3 gm.

of ammonium chloride to produce alkalosis and acidosis respectively. The series of subjects were also given 3 mg. of strychnine daily for a week and one subject took 12 mg. for one day. Strychnine is used as a tonic and is reported to increase the sensitivity of the senses. Whatever the change in the internal state may have been in these cases, none of the stimuli so far tested has shown any recognizable effect upon the taste acuity for P. T. C., which was tested before, during, and after the treatment.

## THE GENE

*M. Demerec and B. P. Kaufmann*

### RESPONSE OF HEREDITARY MATERIAL TO X-RAY TREATMENT

Ten years have elapsed since Muller discovered that X-rays are effective in inducing hereditary changes, but the processes which take place during the exposure to irradiation are as yet not definitely known. It has been found that X-rays induce changes in genes and breaks in chromosomes. However, it remains to be determined whether these changes are produced directly, through direct hits of electrons, or indirectly, through changes in the gene and chromosome environment.

It has been found by a number of investigators that the effect of X-rays, as measured by the frequency of X-chromosome lethals induced in the treated sperm, is independent of the wave length. From the theoretical standpoint results obtained from treatments with long wave lengths (soft rays) are the most significant ones. They are difficult to obtain because of the low penetration of these rays. An experiment conducted in cooperation with Dr. Hugo Fricke, of the Long Island Biological Association, has been completed recently in which the effect of rays of 2.2 Å was compared with that of rays of 0.94 Å. In order to make the exposure uniform, males of *Drosophila melanogaster* were treated individually in a specially designed chamber in which the abdomen was compressed to a thickness of about 0.15 mm. The incident X-ray intensity was determined after every treatment. It averaged about 1360 r-units in each of the experiments. Among 1449 sperm treated with 0.94 Å X-rays, 52 (3.59 per cent) lethals were found; among 1430 sperm treated with 2.2 Å X-rays, 50 (3.50 per cent) lethals were found, while among 2108 controls 23 (1.14 per cent) lethals were observed. These results are in agreement with the results of similar experiments made by Timofeeff-Ressovsky and Zimmer and show that the X-ray effect is independent of the wave length of the X-rays used even for rays as soft as 2.2 Å. The high frequency of lethals among controls was due to the presence of a mutability factor in the Florida stock used in these experiments.

It has been observed in various experiments with X-rays that whenever flies from the Oregon-R (Ore-R) stock were treated the frequency of X-chromosome lethals was lower than when a similar treatment was given to flies from several other stocks. To determine whether this difference was due to a biological difference between stocks, an experiment was performed by Demerec in which an identical exposure was given simultaneously to

Ore-R and to Swedish-b (Sw-b) males. Results of this experiment are as follows:

No. of r-units	Ore-R	Sw-b
Control .....	2/3049 = $0.07 \pm 0.03$ per cent	3/1627 = $0.18 \pm 0.07$ per cent
1000 .....	13/1000 = $1.30 \pm 0.24$	20/1015 = $1.97 \pm 0.30$
2000 .....	18/ 880 = $2.05 \pm 0.32$	23/ 793 = $2.90 \pm 0.40$
3000 .....	10/ 465 = $2.15 \pm 0.45$	23/ 383 = $6.01 \pm 0.82$
4000 .....	19/ 617 = $3.08 \pm 0.47$	31/ 458 = $6.77 \pm 0.79$
5000 .....	22/ 405 = $5.43 \pm 0.76$	25/ 233 = $10.73 \pm 1.37$

It is evident from these results for the five dosages used that the simultaneous treatment consistently produced an effect almost twice as strong in the Sw-b flies as in the Ore-R flies. This indicates the existence of a biological factor which influences the effect of X-rays on heredity. A similar difference was observed in experiments in which Florida and Ore-R stocks were given simultaneous treatments. The rate of lethals in the Florida stock was similar to that observed in the Sw-b stock.

In another experiment significant differences in the sensitivity to X-rays were observed between several of the ten stocks tested. Material was treated with 3000 r-units and the induced frequency of X-chromosome lethals was determined. The lowest frequency,  $1.62 \pm 0.32$  per cent, was observed in the stock homozygous for the Florida mutability factor, and the highest frequency,  $7.22 \pm 0.63$  per cent, was obtained in the Canton, Ohio, stock. It is of interest to note that the stock homozygous for the mutability factor which gave spontaneously  $2.11 \pm 0.50$  per cent of lethals had the lowest rate of induced mutations. Although the difference is not significant, it seems unusual that the spontaneous rate of mutations was higher than the rate of mutations induced by a 3000 r-units treatment. Whatever the cause for this unusual behavior may be, these results reveal that biological factors play an important rôle in the mechanism by which X-rays induce hereditary changes.

One of the strong points in the argument that X-rays induce changes in genes through direct electron hits is found in the observations that the effect of X-rays is proportional to the dosage applied. These observations are based on data in which X-chromosome lethals are used as a criterion. The data, however, hardly reveal the immediate effect of X-rays, since observations are made on second-generation offspring of treated males. An experiment was carried on by Hans Bauer, M. Demerec, and B. P. Kaufmann in which the effect of X-rays was studied by observing in first-generation larvæ chromosome breaks induced in the parent sperm. Data obtained indicate that the dosage-effect curve is not a straight-line but a sigmoid curve. This suggests that caution should be used in overemphasizing the straight-line curve, since that curve may be a residue curve showing the effect of treatment on the portion of the offspring which survived until the end of the test.

All these facts, viz., the observed effect of soft rays, the dosage-effect curve for chromosome breaks, and particularly the observation that the effectiveness of the treatment is influenced by biological factors, suggest



that X-rays may affect genes indirectly through changes produced in their environment.

#### EFFECT OF NEUTRONS ON HEREDITY

A study of the effect of neutrons on hereditary changes in *Drosophila melanogaster* was undertaken as a cooperative project by M. A. Tuve and L. R. Hafstad, of the Department of Terrestrial Magnetism, and M. Demerec, of the Department of Genetics. Male flies were treated in an especially designed celluloid container which was water-cooled to prevent overheating and aerated to insure an adequate supply of oxygen. The flies were exposed to the radiation from beryllium bombarded by 1000-kilovolt deuterons; this radiation is a mixture of gamma rays and fast neutrons. Exposures were measured by a Victoreen condenser-type r-meter, so that relative exposures may be considered fairly reliable. Wall effects and geometry render the significance of the readings obtained somewhat uncertain, and the fact that neutron "dosages" do not come within the scope of the definition of the roentgen vitiates any absolute measurements expressed in terms of roentgens. To avoid any misunderstanding and to emphasize the need for caution, the dosages indicated by the meter accordingly have been termed "pseudo-roentgens." The treated sperm was tested for the frequency of X-chromosome lethals by the use of the standard CLB method. The following results were obtained: control,  $2/3049 = 0.07$  per cent; 250 pseudo r-units,  $11/1602 = 0.69$  per cent; 1900 pseudo r-units,  $31/753 = 4.1$  per cent. These results show that treatment was effective in inducing hereditary changes and also that its effectiveness increased with the dosage applied.

#### NATURE OF HEREDITARY MATERIAL

Breeding evidence indicates that the Y-chromosome, in proportion to its size, carries very few genes. This evidence is supported by the appearance of that chromosome in salivary glands. While the X-chromosome appears, according to Bridges' revision, as a cable over 400 microns long with more than 1000 cross-lines, the Y-chromosome, which in gonial cells is longer than the X-chromosome, shows up as a loose structure, hardly 10 microns in length with about 10 not clearly defined bands. It has been pointed out in the previous reports (Year Books Nos. 34, 35) that when a chromosome is broken a detectable genetic change frequently occurs at the breakage points. This coincidence is so high that it has been suggested that a change in a gene may be responsible for a break in a chromosome. During the past year this possibility has been subjected to an experimental test by Kaufmann and Demerec. If a change in a gene is either responsible for a break in a chromosome or favorable to the occurrence of such breaks, then it is to be expected that chromosomes containing more genes would have more breaks when treated with X-rays. Results of the experiment show that this is not true. In the first-generation male offspring from males treated with 3000, 4000, and 5000 r-units, salivary chromosome analysis showed that breaks occurred with the following frequencies: Y-44, 2L-43, 2R-77, 3L-35, and 3R-58. In metaphase figures these chromosome limbs are of approximately the same length. Since in salivary chromosomes inversions occurring

in Y and also translocations between Y and the chromocentral region of any of the other chromosomes cannot readily be detected, it is to be expected that the observed value for breaks in Y would be lower than the actual value. These data indicate, therefore, that per unit of metaphase length, breaks in Y occur with approximately the same frequency as in other chromosomes, which in turn means that breaks are not caused by changes in genes but rather that a break in a chromosome is likely to induce changes in the adjacent genes. This suggests that the chromonema is similar in the genetically almost inert Y and in the other genetically active chromosomes, and that breaks occur in the chromonema.

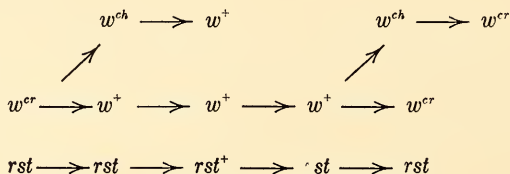
Frequency of the distribution of chromosome breaks was studied by Bauer, Demerec, and Kaufmann. The males of Ore-R stock were irradiated with 1000, 2000, 3000, 4000, or 5000 r-units and breaks were diagnosed by salivary gland analysis of  $F_1$  larvæ. The position of about 1000 breaks was plotted within the limits of the respective sections of Bridges' salivary chromosome map, which divides the chromosome complex into 102 regions. The data show that breaks are distributed at random throughout euchromatic regions but that they are accumulated in heterochromatic regions as they appear in salivary chromosomes. If, however, the length of heterochromatic regions is determined from metaphase plates, the number of breaks per unit of length is similar in both regions and also in the heterochromatic Y-chromosome as indicated in the experiment described above. This suggests that the frequency of breaks per unit length of chromonema is similar in all chromosomes, which indicates a similarity in the structure of their chromonemata. Chromosomes then can be visualized as composed of fiber-like chromonemata, which are structurally similar throughout the whole complex, and to which the genes are linked. Such a picture parallels closely the picture of a fiber protein molecule as outlined by W. T. Astbury. The backbone of the protein molecule may correspond to the fundamental unit of a chromonema and a group of radicals attached to the backbone may correspond to what we call a gene.

The data of the same experiment indicate that when several breaks are induced in a sperm they are not distributed at random but breaks tend to concentrate on certain chromosomes. The distribution of breaks and particularly the study of multiple breaks made by Kaufmann suggests that the fusion of broken parts occurs subsequently to the break rather than that breaks are the result of chromosome fusion as has sometimes been assumed.

An unstable condition affecting white and roughest loci has been studied cytologically by Helen Slizynska and genetically by M. Demerec. In this material, which has the experiment number 258-18, the tip of the X-chromosome is translocated to the chromocentral region of the fourth chromosome. The break in the X-chromosome is to the right of roughest, after the dotted 3C4 line of Bridges' 1935 map, and the break in the fourth is in the section 101F. This aberration was obtained from X-rayed sperm which had wild allelomorphs in white and roughest loci. Thus a break has been induced in the X-chromosome immediately following white and roughest loci. These loci were brought into proximity to the chromocentral region of the fourth chromosome. Moreover, a change in these two loci has occurred which made



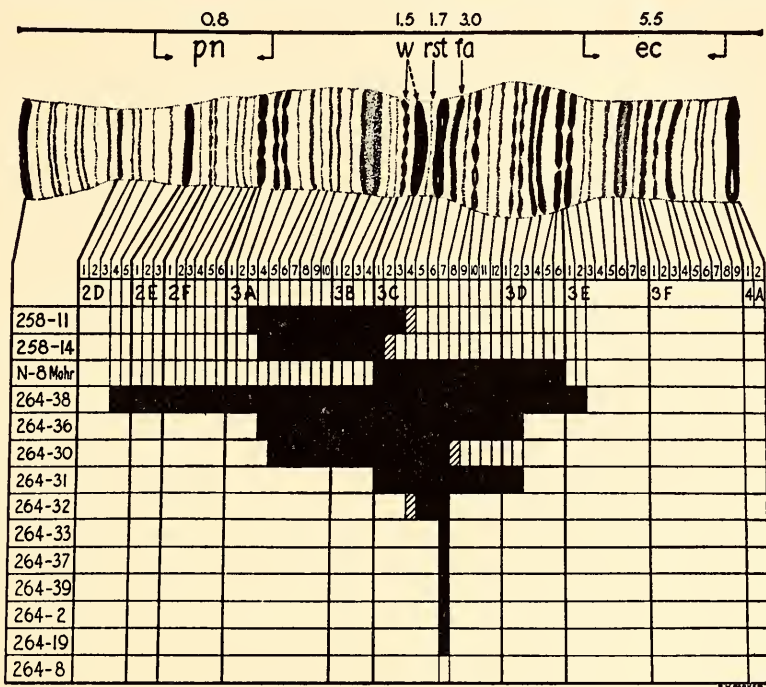
them unstable. The 258-18 is viable in males. The eyes of 258-18 males are cream-roughest with colored spots variable in size, some of which are wild type and some lighter than wild, designated here as cherry. Wild-type colored spots may be smooth owing to change in roughest. In the extreme cases, eyes may be prevalently wild type in color and texture with a few roughest spots on which cherry or cream colored spots may show. Smooth spots (*rst*<sup>+</sup>) have never been observed on cream or cherry background. Such spots appear only on the red colored sectors. Also light spots, either cherry or cream, have never been observed on smooth (*rst*<sup>+</sup>) background, but they always appear on roughest tissues. If the background is used as a criterion for the direction in which changes occur, then the study of patterns appearing on eyes reveals that changes go in both directions, viz., from light to dark and from dark to light and also from roughest to smooth and from smooth to roughest. It is evident, moreover, that changes in roughest and white loci are interrelated. The chain of changes occurring in these loci can be expressed as follows:



This behavior can readily be explained by assuming that *rst* and *w*<sup>cr</sup> genes are in an unstable condition and that chemical changes occurring in these genes are in the nature of reversible reactions.

It was stated in the last year's report that a gene which increases the frequency of mutations occurring in other genes has been discovered in the Florida stock of *Drosophila melanogaster*. Recent experiments by Demerec indicate that this gene is a second chromosome recessive and that it is active during the whole period of the development of germ cells but that it is probably ineffective in inducing mutations in somatic cells. In addition to the Florida stock fourteen other stocks were tested for the frequency of spontaneous X-chromosome lethals. These stocks are Oregon-R; Swedish-b; California-C; Huntsville, Tex.; Urbana, Ill.; Amherst, Mass.; Woodbury, N. J.; Tuscaloosa, Ala.; Lausanne, Switzerland; Seto, Japan; Kyoto, Japan; Wooster, Ohio; and Formosa, Japan; the name of the stock indicating the place of its origin. In the two stocks mentioned last the frequency of changes was significantly higher than in the other stocks, namely, in the Oregon-R stock  $2/3049 = 0.07 \pm 0.03$  per cent lethals were found, while in the Florida there were  $23/2108 = 1.09 \pm 0.15$ , in the Wooster, Ohio,  $8/1266 = 0.63 \pm 0.15$ , and in the Formosa  $8/2054 = 0.39 \pm 0.09$  per cent lethals. If the genetic constitution of these two stocks is responsible for their higher rate of mutability, then it appears probable that there are numerous mutability factors scattered through the different stocks which act in a manner similar to the Florida factor. Since such factors increase

Dr. B. M. Slizynski, of the University of Cracow, Poland, studied salivary chromosomes of 19 spontaneous lethals and of 14 lethals induced by X-rays. All of these are located in the X-chromosome to the left of garnet. In 10 spontaneous and 5 induced lethals he was able to detect small deficiencies extending from one up to nine bands. This finding shows that at least some lethals are deficiencies. Since it is technically difficult to detect a deficiency of a very fine band, it is probable that the proportion of deficiencies among



lethals is higher than indicated in these results. The possibility is not excluded that all lethals may be deficiencies. No difference was observed between spontaneous and induced lethals. One semi-lethal was included in this material and a detectable deficiency was observed in that case also.

Dr. Helen Slizynska studied salivary chromosomes of 14 deficiencies involving the white-notch region. The results of these studies are shown in figure 1. These results indicate that prune is located between bands 2D3 and 3A3, that the locus white is represented by 3C1, roughest by 3C4, and notch by 3C7. Echinus is located to the right of 3E2. In the case of notch 264-8 no deficiency could be detected cytologically. Genetically this notch

behaves like all other notches, viz., it is lethal and cell-lethal and it acts as a deficiency for facet, facet-notch, split, and abruptex. It is possible that, in this case, the gene has been inactivated as far as its physiological activity is concerned but has retained its capacity to produce nucleic acid in salivary gland chromosomes. N-8 Mohr and 264-39 are spontaneous deficiencies; all the others were obtained by X-ray treatment. Figure 1 clearly shows that the changes responsible for deficiencies occur in blocks, viz., that frequently a group of loci is affected by a single change.

Miss Margaret E. Hoover completed a study of an inversion in tandem involving practically the whole X-chromosome. Genetically this material involves a change in the cut locus, and a lethal which, while lethal in the homozygous condition to the organism as a whole, is non-cell-lethal to the hypodermal cells of females. Cytologically three points of breakage have been determined in the salivary gland chromosome, and the heterozygous chromosomes have been observed to form two characteristically looped inversions. The two inversions have a common breakage point at the cut locus following 7B1,2 and preceding 7B5. The first of the two other breaks occurred following 2E3 and preceding 2F3, and the second follows 19A1,2 and precedes 19B1,2. Cytological examination indicates that small deficiencies have occurred at each of the three breakage points.

In a cytological study of mitosis in the neurocytes of *D. ananassæ*, Kaufmann found that the fourth chromosomes, which are the shortest of the three pairs of V-shaped autosomes, are totally heteropyknotic in resting and prophase stages. In salivary gland nuclei these chromosomes are represented by a small bipartite mass of heterochromatin which forms part of the chromocenter. Both in mitotic and salivary gland nuclei the nucleoli are organized adjacent to a terminal satellite in the long arms of the fourth chromosomes. In mitotic prophases of the males, the Y-chromosome forms a third member of the group associated with the nucleolus. Hybrids between a Japanese and an Alabama population of *D. ananassæ* showed four inversions in salivary gland nuclei. One of these inversions is terminal, a type previously undescribed.

#### THE STUDIES OF DR. T. DOBZHANSKY

Theodosius Dobzhansky, one of the guest investigators, has been working on *Drosophila miranda* and its hybrids with *D. pseudoobscura*. *Drosophila miranda* possesses an exceptional mechanism of sex-determination: instead of the two X-chromosomes in the female and one X and one Y-chromosome in the male encountered in all other known species of *Drosophila*, this one has two pairs of X's ( $X^1$  and  $X^2$ ) in the female, and one  $X^1$ , one  $X^2$ , and one Y-chromosome in the male. At meiosis the  $X^1$  and Y chromosomes pair and go to the opposite poles of the spindle, while the  $X^2$  seems to go, in more than 99 per cent of cases, to the same pole with the  $X^1$ . Since at no stage does the  $X^2$  chromosome pair with either  $X^1$  or Y, the situation is very extraordinary indeed; it seemed desirable to secure a genetic proof that the behavior of the heterochromosomes is in fact in accordance with the scheme just outlined. Such a proof has been obtained by studying cer-

tain exceptional classes of offspring appearing in the hybrids between *D. miranda* and *D. pseudoobscura*.

If males of *D. miranda* are placed together with a mixture of females of *miranda* and *pseudoobscura*, many intraspecific, and only a few interspecific, matings take place. The same is true if males of *pseudoobscura* are placed with a mixture of *pseudoobscura* and *miranda* females. This phenomenon of preferential mating has been studied quantitatively. It has been found that different strains of *D. pseudoobscura* exhibit different degrees of aversion from mating with *miranda*; preliminary results indicate furthermore that the greatest degree of isolation is observed if strains of *pseudoobscura* coming from the geographical region where *miranda* occurs are used. On theoretical grounds such a phenomenon is not unexpected, since natural selection ought to bolster up the mechanism of sexual isolation mainly in populations inhabiting the geographical regions where the two species in question occur together.

Theodosius Dobzhansky and Hans Bauer have cooperated on a study of the gene arrangements in two species, *D. athabasca* and *D. azteca*. These two species can be crossed; the hybrids produced are completely sterile. The salivary gland chromosomes have been studied in the larvæ of the first generation of hybrids. Judging by the observed instances of pairing of the salivary chromosomes, the gene arrangements in the two species must be profoundly different. Only one of the chromosomes (an autosome) is found paired at all frequently; in all other chromosomes instances of pairing are very rare, and when they do occur only very short sections are involved. The differences between the arrangements in the two species are due mainly, if not exclusively, to inversion of chromosome sections. Sometimes rather long, but mostly very short sections are involved. This investigation will be continued.

#### STUDIES IN LEUKEMIA

*E. C. MacDowell, J. S. Potter, J. Victor, M. J. Taylor, T. Laanes,  
E. N. Ward, and M. P. Wintersteiner*

Under a grant of the Carnegie Corporation to the Carnegie Institution of Washington, the analytical study of leukemia in mice has been continued at the Department of Genetics and at the Department of Pathology, College of Physicians and Surgeons, Columbia University.

A current opinion states emphatically that genetic variables are insignificant in the cancer problem. This is based on the discovery of experimental conditions under which genetic differences in animals do not influence the results. To establish conditions that fail to reveal the operation of a given set of variables is poor evidence that such variables do not exist. Under appropriate conditions the experimental studies on mouse leukemia have consistently demonstrated the effective operation of genetic variables. During the past year evidence of the profound influence of genetically controlled specificities has been considerably extended. In this, the significance lies not in the fact that genetic control may play a decisive rôle, but in the



opportunity given by this kind of control to interpret the nature of the processes observed by controlled experimental analysis.

In more concrete terms, we have previously reported the experimental induction of resistance to transplanted leukemic cells of known properties by means of treatment with embryonic tissue. In these studies the intrinsic specificities of the hosts, of the leukemic cells, and of the embryonic tissue are all rigidly controlled, both in the sense of maintaining a high degree of constancy and in that of providing hosts, leukemic cells, and embryos with a range of different intrinsic properties.

If the leukemic cells and the hosts are held constant, the outcome can be varied from resistance in all cases, to resistance in part of the cases, to resistance in no case, by varying the genetic constitution of the embryos. We can now report experiments in which the hosts and embryonic tissue have been held constant while leukemic cells with different intrinsic properties were used. These studies were undertaken in search of an interpretation of the striking failure of treatments that induce resistance to transplanted leukemias and other malignant growths to resist the spontaneous occurrence of new-growths (Year Book No. 34, p. 48). An interpretation widely accepted is that an animal cannot be immunized against its own cells. Accordingly, investigators have abandoned this line of approach. However, we have proposed an alternative interpretation; namely, that malignant cells in the original animal are significantly different from those passed through a long series of hosts and that the untransferred cells to be resisted require correspondingly different treatments of the hosts.

We have abundant evidence of various kinds indicating differences between populations of leukemic cells as found in spontaneous cases and such populations after transplantation through a long series of hosts. Of the differences the most obvious is the relatively low virulence of cells in spontaneous cases and the extremely high virulence that may be developed in the course of successive transfers. To suggest that such differences might account for the failure of supposedly immunized hosts to resist their own spontaneously occurring malignant cells involves the paradoxical assumption that induced resistance powerful enough to inhibit highly virulent cells is unable to resist cells of low virulence. However, our experiments demonstrate conclusively that this is the case; that the unique relationship between an animal and its own cells is not the cause of the past failures to induce resistance to spontaneous new-growths. These results open the door to a search for treatments that will induce resistance to leukemic cells of spontaneous cases. In these critical experiments leukemic cells were transferred directly from the animals in which they appeared spontaneously into mice rendered resistant, by the appropriate embryo tissue, to many-times transplanted leukemic cells. All possible biological variables were checked by rigid control tests within each unit experiment.

*Without* embryo treatment, the leukemic cells directly from the spontaneous case, as well as those from the long series of transfers, killed all the animals, but the same number of "spontaneous" cells required many times as long to kill. *With* embryo treatment, every mouse resisted the highly virulent long-transplanted cells, as expected; but the mice with the



spontaneous cells far less potent, as compared with their litter mates without embryo treatment, did not show the slightest evidence of any resistance. Thus, with the correlation between "spontaneous" cells and the mouse giving rise to them broken by transferring these cells to another host, the comparison with the behavior of long-transplanted cells is made directly against a common background, and the spontaneous cells are found to be more resisted than they are within their own mouse when it is similarly treated (see below).

While spontaneous cells are less virulent than those long transplanted, there is still variation between different spontaneous cases. This appeared in the cells from the six different spontaneous cases used in six unit experiments. All these experiments agreed in showing a complete absence of resistance due to embryo treatment, but in certain cases undeniable evidence appeared that the embryo treatment significantly hastened the growth of the "spontaneous" cells and shortened the interval before death. The controls in these experiments were of such a nature as to preclude any other interpretation than that the condition in the hosts induced by the embryo tissue resisted the growth of one kind of leukemic cells and favored the growth of another kind. In the experiments showing accelerated growth, the "spontaneous" cells were the least virulent, so that a systematic relationship appears between the degree of virulence and the effect of the embryo treatment in this particular combination of hosts and embryos; the lower the virulence the less effective is the resistance, until cells of the lowest potency are actually facilitated.

The study of the influence of embryo treatment on the incidence of cases of spontaneous leukemia has been completed this year. As indicated above, this treatment has failed to lower the 90 per cent incidence of spontaneous leukemia characteristic of this strain (C58). The untreated control mice were litter mates and passed their entire lives in the same boxes as their sibs that received monthly inoculations of the prescribed embryonic tissue. As expected, 90 per cent of the 56 controls died with spontaneous leukemia; but all of the 60 test animals (not counting one undiagnosable case) died with spontaneous leukemia. Further, the frequency distributions show that the tests tended to die at an earlier age than the controls.

This result is consistent with the conclusion from the transplantation experiments: that this particular embryo treatment fails to resist "spontaneous" cells and in some cases actually favors their growth, whether in the mouse giving rise to them, or transplanted in another host.

In spite of the differences in the mechanisms of resistance induced by embryo treatment and by repeated sublethal doses of leukemic cells themselves (Year Book No. 35, p. 48), the above results parallel those from the corresponding studies on the latter type of resistance (Year Book No. 34, p. 48) and stress as outstanding the point that malignant cells of low and high virulence require different conditions to be resisted. As spontaneous cases are usually of relatively low virulence, leads in the search for methods of resisting spontaneous cells are not to be sought with long-established

highly virulent transplanted tumors but rather with malignant cells of low virulence as found in the first transfers from a spontaneous case.

The foregoing general conclusion, although expressed in practical terms, challenges theoretical interpretation. Increase in virulence due to transfer has been plausibly explained by numerous authors as the result of a selective process whereby an originally small proportion of highly virulent cells gradually become the dominant type. This assumes that a spontaneous case includes malignant cells of various potencies and each cell type reproduces itself. The actual facilitation of the growth of "spontaneous" populations of leukemic cells by the embryo treatment stands as direct evidence against the above assumption. As long as the nature of the processes of induced resistance remains concealed, a full interpretation is not possible, but a contribution to this interpretation has been made by a new concept of malignancy that has been gradually developed during recent years by Potter and crystallized this year by studies growing out of the modifications of leukemia reported last year.

That a malignant cell is a changed normal cell is generally agreed; in many minds, it is a changed cell that is able to reproduce itself indefinitely. The strong morphological trend of early biological science and the weighty influence of conceptions of species and mutation may be responsible for this idea, according to which tumor cells correspond to unicellular parasites; tumors, even of the same tissue, differ as to varieties or species of independent organisms. Much of the experimental work on tumors fits easily into this point of view. But in the case of leukemia there have constantly appeared difficulties.

The continued study of the experimental leukemias emphasizes more and more the close similarity to normal processes rather than the pathological aspects so conspicuous in other malignant tissues and so generally emphasized in tumor studies. In leukemia many such pathological phenomena are lacking, yet malignancy unquestionably remains, the more directly to be studied. Indeed, the malignant cells of the various leukemias so closely resemble normal cells in their morphology and in their processes of differentiation that significant contributions to the understanding of the normal processes of differentiation are being made as one of the highly significant outcomes of this project. The stages of differentiation of white blood cells are numerous and conspicuous; in the absence of malignancy these tissues are so highly labile that the normal relationships of different white blood cells has remained one of the most difficult problems of development. With a variety of stable populations of transplanted leukemic white blood cells available for study, we were first impressed by the constancy of the specific differences; at present it appears even more significant that in all constant leukemic populations the range in cell types is the same; that the course of differentiation is the same, and further that both the range in types and the course of differentiation is the same as in normal lymphoid tissues. Even though the leukemic population has become highly stabilized by passages through hundreds of successive hosts, every sample of the population shows the whole range of differentiating lymphoid cell types. The *fre-*

quency of the different cell types characterizes different populations. These specific differences, therefore, are not due to the isolation, here of one self-reproducing cell type, there of another, but to *differences in the rate of differentiation*. Malignant lymphocytes differentiate more slowly than normal, but the process of differentiation is still going on and a certain number of fully mature cells are constantly being formed; this reduction in the rate of differentiation results in the accumulation of large numbers of more primitive types. The rate of differentiation is related to the degree of virulence—the slower the development, the more virulent the population; the larger the proportion of primitive cells; the higher the metabolic rate; the more rapid the growth of the population. The control of this rate lies primarily within the cells themselves, and the whole population is called leukemic, but to the extent that any given cell progresses along the course of differentiation, its malignant properties are limited, until upon reaching the final stage of a mature small lymphocyte, it may no longer be rightly considered malignant. The transmission of the malignant property in an experimental population depends upon an unbroken succession of immature types; and this in turn is subject to the existence of suitable surrounding conditions.

Thus Potter proposes that malignancy should be considered a modification of the rate of normal differentiation, not a new “species” of cell produced by some saltation. This concept has a bearing upon all the various types of results that have been accumulated in this whole program, and a full discussion of the unification brought about thereby cannot be attempted in this place. In relation to the work on virulence and resistance reported above, this view permits the substitution of the word “immature” for “virulent”; the general conclusion then becomes: the more immature the leukemic cell types, the more easily resisted by the procedures under investigation.

#### ENDOCRINE STUDIES

*O. Riddle, R. W. Bates, J. P. Schooley, G. C. Smith, E. L. Lahr, and  
M. W. Johnson*

The anterior pituitary gland produces hormones which exert a large part of their action on other hormone-producing glands. Studies on this “master gland” therefore necessarily involve examination of pituitary effects produced in many or most of the endocrine organs of the body. It is now well recognized that the pituitary thus directly and indirectly shares in regulating not only the processes of living or maintenance, but also those involved in the development of body and mind. These relations of the pituitary gland to maintenance and development continue to engage the activities of Dr. Riddle and his associates.

Many laboratories have contributed notably to our knowledge of the pituitary gland during the past year; but a clearly defined trend of fact and opinion on such a basic question as the probable number of anterior pituitary hormones is not yet evident. Perhaps most investigators are inclining to the view that but few wholly distinct hormones are produced; still other



investigators nevertheless report evidence for additional hitherto unrecognized pituitary products. In general, our own studies—greatly aided by a grant from the Carnegie Corporation of New York to the Carnegie Institution of Washington—continue to disclose additional effects of the hormone prolactin and to suggest that total pituitary function is accomplished by very few hormones.

#### FURTHER STUDIES ON ACTIONS OF PROLACTIN

It was reported last year that injections of prolactin into doves and pigeons rapidly and greatly enlarge the livers of these animals, though other pituitary hormones seemed unable to elicit this response. Extension of that study by Bates, Riddle, Lahr, and Schooley has now shown that still other parts of the viscera are similarly affected, and that an overgrowth (splachnomegaly) of the liver and intestine follows prolactin dosage in both normal and hypophysectomized pigeons. Gonad-stimulating and thyrotropic hormones administered together do not increase or produce this effect in such birds. Liver size in operated birds was almost doubled during 10 days by daily injections of 30 units of prolactin; intestinal length (also body weight) simultaneously increased 25 per cent over that of operated controls and 9 per cent over that of unoperated controls (9, 10, and 18 tests), and intestinal weight was 95 per cent greater in injected than in their uninjected controls (9 and 10 tests). The injection of an unfractionated pituitary extract (containing prolactin and all other pituitary hormones) increased all these several prolactin effects on visceral overgrowth and on body growth. Under treatment with purified prolactin the weight of the pancreas of hypophysectomized pigeons decreases less than in untreated controls. Some other pituitary hormone(s) seems, however, to have a like action on the pancreas, and here the combined action of pancreas-sustaining hormones has been found to give pancreas weights (1.84 gm., 7 tests) even higher than that for the pancreas of unoperated controls (1.42 gm., 18 tests). In operated untreated controls the pancreas weight was 0.64 gm. It therefore appears that for maintenance of normal weight or for production of overgrowth in the bird's pancreas prolactin acts either additively or synergistically with at least one other pituitary hormone.

From such of the above tests as were made on hypophysectomized pigeons still other valuable information was obtained from measurements of food and water intake made by Dr. Schooley. A relation of "appetite" and food intake to observed changes in body size and organ size resulting from hypophysectomy or from the injection of one or another pituitary hormone was thus disclosed. Reference to specific findings is made later in this report.

Thus in hypophysectomized pigeons a fairly good increase in body weight was obtained with prolactin, which notably increased appetite and stimulated digestive organs to overgrowth. Pronounced growth was obtained with the unfractionated pituitary extract (all pituitary hormones), which, besides accentuating all these prolactin effects, also sustained and overstimulated (as prolactin did not) the thyroids, gonads, and adrenals. In other words, in 2-month-old pigeons with no pituitary glands the growth process

was promoted by one pituitary hormone (prolactin) which promotes appetite and overgrowth of digestive organs; this growth process was partly sustained by other prolactin-free pituitary fractions which, incidentally or otherwise, repair other important endocrine organs. These data therefore provide additional reason to doubt the separateness or singleness of a "growth" hormone in the pituitary.

Still other data on organ weights obtained from uninjected normal pigeons studied at 21 and 28 days after hatching indicate that prolactin shares in the very rapid growth of these young pigeons, and indeed that it then also produces a temporary overgrowth (splanchnomegaly) in their livers, intestines, and pancreas. The decisive data were obtained from 63 of these younger birds and from 57 birds 20 to 27 days older. All these birds were of the same race (Carneau); the older birds had almost completed their growth and were growing very slowly. It was found that the crop sacs of the younger and rapidly growing groups were relatively and absolutely enlarged, showing that the pituitaries of these very immature birds were then releasing prolactin in unusual amounts. Concurrently their livers, intestines, and pancreas were all disproportionately large in relation to the size of their bodies. These data and their statistical analysis have been published.

Two other studies provide special information concerning chemical and histological conditions in livers of normal and hypophysectomized pigeons forced to rapid growth under the action of injected prolactin. The water and salt content of these livers (and of the muscles of the same birds) were shown by Bates and Riddle to be only slightly influenced either by hypophysectomy or by prolactin treatment which quickly doubled liver size. On the other hand, Drs. Johnson and Riddle have found that prolactin induces the storage of marked quantities of fat in the liver; they further found that this storage is accentuated—probably up to 30 or 35 per cent—by those prolactin preparations which have the added property of stimulating the adrenal cortex. Best and Campbell had earlier shown that whole pituitary extracts have power to cause fat storage in the livers of rats.

In a related study Schooley and Riddle have measured the size changes which cyclically occur in the liver and testes of adult healthy male pigeons during periods of prolactin production (incubation, feeding young) and during other periods when prolactin is apparently not being secreted (mating, resting). It is notable that these observations involved no injections or treatment whatever, and the values found should at least partially reflect the action of physiologically normal amounts of this hormone on the liver and testes. Ninety-five males supplied data concerning the size of these organs at times when detectable amounts of prolactin were not being secreted. The measurements made on 27 males during incubation (prolactin being produced) indicated that their livers were 12 per cent heavier and their testes 11 per cent lighter than in non-prolactin periods. In 21 additional males studied after a still more prolonged period of prolactin production (feeding of young stage) these organ weight changes were maintained or accentuated, and sperm formation in the repressed testes was also then



found to be diminished. In earlier reports it was noted that injections of prolactin into adult pigeons markedly increase liver weight and greatly diminish testis size. It is therefore probable that prolactin cyclically produced in the bird's own pituitary is responsible for both liver enlargement and testis repression during the four or five weeks which male pigeons periodically spend in the incubation of eggs and in the feeding of young.

An earlier report noted that prolactin acts adversely on the adult germ glands of pigeons and fowl, and probably also on the ovaries of rats. During this year Bates, Riddle, and Lahr have successfully studied the mechanism by which prolactin thus affects the gonads. Suitable tests now show that prolactin, or some unrecognized substance contaminating all our prolactin preparations, so acts upon the animal's own pituitary as to cause it to discontinue the release of gonad-stimulating (F. S. H.) hormone. This latter hormone first develops and later sustains the size and activity of the testis and ovary, and the action of prolactin is thus upon the pituitary and only indirectly upon germ gland tissue. A similar suppression of the output of one pituitary hormone by an overabundance of another hormone formed in that same gland has not been observed hitherto. The suppression of gonad growth in the juvenile pigeon might be regarded in this way. The results of this study therefore have both theoretical and practical importance.

Work reported last year was thought to make it probable that the word "adrenotropin" applies to the same pituitary hormone which had been earlier isolated and named prolactin. Early this year Lyons and Moon, of the University of California, partially reported evidence that prolactin and adrenotropin are two now incompletely separable hormones. This question is being studied further by Riddle, Bates, and Lahr. Intimately associated with this problem is the identity of the hormone responsible for the diabetogenic, or blood-sugar-raising, action of pituitary extracts. Last year Riddle and Dotti reported data indicating that in birds and rabbits this action is probably associated with prolactin, although, as Britton had earlier found in mammals, the hormone of the adrenal cortex likewise increases the blood sugar of pigeons. Our study of this point is being continued.

The basal metabolism studies conducted with the assistance of Mrs. Guinevere C. Smith have contributed much toward clarifying some currently studied endocrine problems. Three such items are notable under this subdivision of the present report. Repeated measurements made this year on a group of thyroidectomized pigeons adequately prove that in pigeons measured at 30° C. prolactin increases (+13 to +20 per cent were observed) the basal metabolic rate (B. M. R.) in the absence of the thyroid gland. Thyrotropic hormone, when made quite free of prolactin, had no power to affect the metabolic rate (+1 per cent) of these same animals (17 tests). In confirmation of earlier work, prolactin markedly increases the B. M. R. in complete absence of the pituitary; 8 such pigeons injected daily for 4 to 6 days with 18 units of prolactin showed an increase of 33 per cent, and when given 30 units daily an average increase of 60 per cent was found. Finally, further study of an apparent slight effect of the adrenal cortical hormone (cortin) on the B. M. R. of pigeons (57 tests) has clarified this subject. The apparent

slight effect of repeated daily dosage with cortin is found to result indirectly from a longer retention of food in the alimentary canal—and thus an inadequate fasting period—of cortin-injected birds. Values obtained from birds injected only at the end of their 24-hour fasting period, and studied immediately (48 measurements), show no variation from uninjected control values.

During three years Riddle, Lahr, and Bates have conducted a comprehensive study of the relation of prolactin and many other hormones and substances to maternal behavior in young rats. This study is still incomplete. The ability of cortin, several sex hormones, intermedin, phenol, and other substances to initiate or to repress maternal behavior has received much attention. A summary statement concerning these prolonged observations should be reserved for next year.

Since the biological assay of prolactin is usually and best done by measuring its effect upon the crop glands of pigeons, it became necessary to extend our information on the question whether the absence of either the pituitary or the adrenal glands modifies the extent of the crop-gland response. Further information was obtained by Drs. Schooley, Riddle, and Bates. In all of 20 pigeons completely hypophysectomized from 1 to 287 days earlier, the crop sacs responded effectively by growth, and often by crop-milk formation, to prolactin injected over a 4-day period. These complete responses were obtained both in very immature and in adult individuals. Quantitative measurements made on the operated adults show, however, that their crop-sac response is only about one-eighth that of unoperated mature pigeons. Complete adrenalectomy did not prevent the usual response of the crop sacs to prolactin in a test started 4 days after operation. Thyroidectomy did not significantly affect the usual crop-sac response to prolactin in a pigeon operated 176 days earlier.

#### NUTRITION AND GROWTH RESPONSE IN PIGEONS

At 44 days after hatching Carneau pigeons have attained a body weight (480 gm.) approximately 80 per cent of that of fully mature birds, and during the next 10 days their weight is increased by about 5 gm. Dr. Schooley has found that during this 10-day period, and at a particular season, such squabs daily consume about 37 gm. of dry grain and 74 cc. of water. Simply removing the pituitary gland at 44 days reduced this daily intake to 6 gm. and 57 cc. with a resulting loss of 20 per cent in body weight. Pituitary removal followed by forced feeding of 36 gm. daily prevented 90 per cent of such loss in weight, but such feeding did not sustain the bird's thyroids, gonads, and adrenals. Pituitary removal followed by injections of 25 units prolactin daily during the 10-day period resulted in a voluntary daily consumption of 33 gm. and 74 cc., and an average weight gain of 32 gm. per bird; as before, thyroids, gonads, and adrenals were unaffected. Pituitary removal followed by injection of an extract containing all pituitary hormones was accompanied by voluntary consumption of 33 gm. daily and an average increase in body weight of 50 gm., with an overgrowth of thyroids, gonads, and adrenals. Pituitary removal followed by the injection of two other pituitary fractions made free of prolactin resulted in daily food intakes of 24 and 16 gm. (47 and 62 cc. water), with body weight losses of 20 and 62 gm.,

respectively, and with varying effects upon thyroids, gonads, and adrenals.

These results carry a suggestion that various pituitary hormones may stimulate "appetite," as well as repair or sustain certain endocrine organs, and to varying extents they may thus affect gain or loss of body weight when injected into hypophysectomized animals. Again, factually it was found that simultaneous administration of the several (unseparated) pituitary hormones into hypophysectomized young pigeons resulted in the greatest increase in body weight, this increase much exceeding that found in the normal unoperated birds. This observation on the growth response again suggests a synergizing, or at least a supporting, effect of pituitary hormones administered together.

Drs. Riddle and Schooley are studying still other aspects of growth which may involve intimate relationships between nutritional and endocrine factors.

#### SEX HORMONES AND SERUM CALCIUM

It was reported last year that the gonad-stimulating hormone is capable of increasing the serum calcium of suitable pigeons. Continuation of those studies by Dr. Riddle, in association with Dr. Louis B. Dotti, of New York Medical College, has notably advanced our knowledge of one aspect of the mechanism by which calcium metabolism is regulated. The new data indicate that the sex hormones produced by the ovary, but apparently not those produced by the testis, are able to mobilize and bring into the blood increased amounts of calcium. It was found that sufficient and prolonged dosage of certain female sex hormones have great power (theelin), others notably less power (dihydrotheelin, theelol, progesterone), to increase the serum calcium in normal, castrate, hypophysectomized, thyroidectomized pigeons and rats, and in normal doves, fowl, and dogs (the results are slight or absent in rabbits). The male sex hormones testosterone, its oxime, and androstenediol have no similar or demonstrable power to increase the level of calcium in the blood of these animals.

The extent to which this disclosure assists in clarifying phenomena observed in animals and man is an intriguing, though now a rather speculative, subject. Some probable applications in physiology are fairly obvious. In medicine it should provide a somewhat surer appraisal of certain abnormal female states, and possibly disclose the true basis for the benefit currently derived from theelin administration in some mental cases. To students of sex difference it certainly assists a comprehension of the skeletal and mineral metabolism differences which were quite inexplicable so long as the "asexual" thyro-parathyroid apparatus and vitamin D (this latter being chemically related to the sex hormones) were considered to be the prime supervisors of the utilization and deposit of lime. Remembering the more prolonged epiphyseal growth of the bones in human castrates, the anatomist and anthropologist may also give consideration to the circumstance that all the several sex cycles of females probably involve temporary interruption of calcium deposit (actual extraction?) in the bones, and perhaps thus account for a lower stature in sister than in brother; again, since these sex cycles begin earlier in some individuals and races than in others, the new fact may assist, even if



slightly, our understanding of the complicated problem of the statural differences of individuals and races.

#### STUDIES ON METHODS

Attempts to dissociate and recognize the component parts of prolactin have provided an interest in the amino acid tryptophane, and a rapid method for the quantitative determination of tryptophane has been developed by Dr. Bates. In the method proposed by May and Rose the maximum development of the blue-colored compound, formed by union of the p-dimethylaminobenzaldehyde with the indole ring in the presence of 6N HCl, is obtained only after 2 days in an incubator, or still longer at room temperature. It was found possible to accelerate this color formation both by addition of a suitable accelerator (nitrate ion) and also by developing the colored compound in 10–11N HCl. Both nitrate ion and concentrated acid accelerate color formation with all other aldehydes studied, and with indole, skatole, and indole propionic acid as well as with tryptophane and with proteins that contain tryptophane. Two quantitative procedures are proposed. The most rapid method combines both means of acceleration, and at room temperature it requires only 30 minutes for completion. The less rapid method employs only the addition of the nitrate ion and requires 4 to 8 hours at 37° C. Casein unknowns can be determined as accurately as one can match the colors, i.e., with a maximum error of about 2 to 3 per cent.

A technique for removal of the pituitary glands of pigeons is a matter of much consequence to the studies of this laboratory and is proving of much interest to several investigators elsewhere. Dr. Schooley, using the parapharyngeal route, has developed a most satisfactory technique by which the posterior lobe may be left essentially intact and under which nearly all operated animals survive.

#### CHAPTERS ON THE PITUITARY PREPARED FOR VARIOUS BOOKS

During the past year members of the laboratory have been called upon to contribute several chapters, of review or of specialized nature, to various books now in process of publication. The time consumed in such work has been so considerable as to warrant notation of this effort here. "The cytology of the anterior pituitary" was written by Dr. Schooley for volume V of the Cold Spring Harbor *Symposia on quantitative biology*. "Methods for the assay of prolactin" was written for the same volume by Dr. Bates. Other chapters, "Physiological responses to prolactin," also "Carbohydrate metabolism in the pigeon," were contributed by Dr. Riddle to the same volume. A chapter on "Preparation, assay and action of lactogenic hormone" was written by Drs. Riddle and Bates for a new edition of *Sex and internal secretions*. A chapter on "Prolactin" was written for a 1937 issue of the *Journal of Nervous and Mental Disease* by Drs. Riddle and Bates. The Ohio State University Chapter of Sigma Xi is publishing a series of lectures in book form; the chapter on "The hormones of the anterior pituitary" was prepared by Dr. Riddle. A chapter on "Endocrine glands and growth" was pre-



pared by Dr. Riddle for *The development of the child*, a book sponsored by the National Congress of Parents and Teachers and by the American Academy of Pediatrics.

## STUDIES IN EUGENICS AND HEREDITY

*H. H. Laughlin*

### THE COEFFICIENT OF PREDICTION-ACCURACY

The specifications for a sound formula for the measure of prediction-accuracy require that, regardless of its source, if we have in hand a prediction in terms of probability-distribution, and if the subsequently determined actual distribution corresponds exactly to the prediction-distribution, it is evident that the particular prediction is perfect and that, consequently, the coefficient of prediction-accuracy in this case should equal 1.00. If, in another case, there be less than 1 per cent of such overlapping of the predicted and the real distribution-areas, then the formula for the coefficient of prediction-accuracy should work out in a value less than 0.01. If, in still another case, exactly three-fourths of the two distributions actually overlap, then the coefficient of prediction-accuracy should register 0.75, and so on. Thus the coefficient of prediction-accuracy is properly measured by that portion of cases common to both the prediction and the subsequently determined facts, each as a probability-distribution.

In the development of the coefficient of prediction-accuracy, use is made of the principle that if the highest probability-class value be constant, the probability-distribution area, that is, the total population, varies directly with the standard deviation, and conversely, if the standard deviation be constant the area varies directly with the highest probability-class frequency.

Three cases are found to cover the various possible situations in which a prediction-distribution area of 1.00 has any given height and skewness, and its subsequently determined overlapping actual distribution-area of 1.00 has any possible height and skewness. These three cases are as follows: Case 1 is characterized by that set-up in which on the subject-quality scale one common probability value lies below the two fluctuation centers or highest probability-class values and the second common probability value lies above these two centers. Case 2 is characterized by that set-up in which there are two probability values on the subject-quality scale, one of which lies either above or below and the second between the two fluctuation centers. Case 3 is characterized by that set-up in which both the predicted and the actual areas possess the same highest probability-class value and each area is either bisymmetrical or skewed but, if skewed, the relationship between the two areas in the same frame of coordinates is that of a right-and-left mirrored figure.

### GENETICS OF THE THOROUGHBRED HORSE

As an experimental animal the Thoroughbred horse, on account of its size, cost, and slow breeding, is not a laboratory animal, but the actual

laboratory work on the measure and inheritance of racing capacity can be carried on with great accuracy: the pedigree records are accurate; the purpose of breeding is clean-cut and definite—the production of racing capacity; and in the race performance of the animal, the sex is recorded and the weight-carried, distance-run, speed, and age are as accurately measured as if the whole purpose of the breeding and racing were a laboratory experiment instead of a major sport.

During the year basic studies continued on the actual resemblance of measured racing capacity in the thoroughbred foal and in each of its several near blood-kin with a view to computing the net resultant of the influence on the foal of several selected near kin, each with a definitely measured racing capacity as one piece of prediction-evidence. Efforts continued also to perfect and to simplify the procedure by which the probability-resultant, as a general biological principle described in last year's report, can be applied practically and more readily in the probability-prediction of racing-capacity distribution among thoroughbred foals. That is, the purpose of such computation is to find by what probability the racing capacity of the foal will fall within any given racing-capacity range, provided that the individual foal develop normally and that all unused evidence-factors be randomly represented.

Special efforts were made to simplify the longer mathematical computations of the probability-resultant and to supply convenient tables and procedures which the breeder could use more readily to compute the probability-distribution of racing capacity among foals with a definite inheritance as above described.

#### THE "BROWN BOOK"

Just as several years ago the so-called "Black Book" reduced and presented in useful tables the mathematical formula which coordinates weight-carried, distance-run, age, sex, and speed in the measure of racing capacity, so now the so-called "Brown Book" has developed to a point where it too may be used practically by the breeder. The "Brown Book" provides, in useful form, two things which the theoretically sound but more complicated procedures in the computation of the inheritance of racing capacity were unable to provide. These two more practically useful things are, first, the development of an empirical method of approximating the fluctuation-center in the probability-resultant (a more detailed discussion of this development is presented in the present report under the heading "Further studies in the probability-resultant"); second, the completion of a set of probability tables computed for each of the following twelve near blood kinships at one-pound racing intervals for the particular prediction-kinship and at five-pound stretches of racing capacity predicted in the foal: (1) sire—foal; (2) dam—foal; (3) sire's sire—foal; (4) sire's dam—foal; (5) dam's sire—foal; (6) dam's dam—foal; (7) full sibs—foal; (8) half sibs, common sire—foal; (9) half sibs, common dam—foal; (10) nephew or niece—foal; (11) uncle or aunt—foal; (12) first cousin—foal.

## FURTHER STUDIES ON THE PROBABILITY-RESULTANT

## THE DIFFERENCE BETWEEN THE AVERAGE PROBABILITY AND THE PROBABILITY-RESULTANT

Although in each case  $K = f(R)$ , that is, probability is a function of the thing predicted, the specific functions are very different in the two cases. The average probability is properly applied to a number of repeated determinations of probability-distribution, in each of which the same pair of coordinate scales is used and the same quality and class-ranges are the subject of distribution. The average probability-distribution is a smoothing of differences which are due to imperfect technique of measuring and to variation in the representative nature of the samples taken, which differences creep in during the measure of different samples of the same population. Thus many repeated distributions of offspring-value in reference to the same trait within the same kinship constitute the "situation and data" for computing the average probability.

On the other hand, the probability-resultant is very different in nature and purpose. The essential feature of the probability-resultant is that each of its constituent probability-distributions, although as in the average probability the subject and class-range of prediction be constant, is entirely independent as a causal or constituent factor in the thing-predicted. The use of one such independent factor requires that all of the unselected factors of the particular result be randomly represented. In the final resultant the several selected independent factors, of course, interact with each other to produce the final distribution of values which is found. Thus the average probability is the end reached by measuring the same thing more than once, while the probability-resultant is reached by measuring several independent but constituent factors of varying effect upon their common result. In this latter sense different blood kinships are rated as independent factors in the inheritance of a measurable inborn quality. The constitutional nature of racing capacity in the thoroughbred horse for each of the several selected near blood-kin of the preindicated foal is thus considered as one independent factor in the probability-resultant which measures the probability that the racing-capacity value which will develop in the foal will fall within any named racing-capacity range, all unselected factors being randomly represented.

Another outstanding characteristic which differentiates the probability-resultant from the average probability is that as additional independent constituent probability-distributions are added to a probability-resultant, the evidence points still more strongly to the thing's happening at the point of the highest common probability, that is, at the *FC*, and, as in every case in which there is a piling up of independent evidence, as in court procedure under law or in any other situation wherein the truth is sought, while each such additional independent evidence points more strongly toward the thing's happening at a given value, each such addition necessarily and simultaneously discredits more strongly the probability of the thing's happening or the truth's being located at an extreme point suggested as possible by any one of the several constituent probability-distributions. Thus seeking the truth by the consideration of independent evidences, rather than

of repeated evidence from the same source, tends to increase the probability of one value's being true and tends to discredit strongly certain other possibilities. The principle of the probability-resultant which has been developed by these researches demonstrates mathematically the above listed observations.

THE DETERMINATION OF THE FLUCTUATION-CENTER, *FC* (THE LOCUS OF THE HIGHEST COMMON PROBABILITY, H. C. P.)

In determining the mathematical formula for any two-dimensional probability-distribution, whether an independent distribution or a probability-resultant, it is necessary to find on the quality-scale, that is on the *R*-coordinate, the locus of the highest probability or the fluctuation-center, the *FC* as herein used. The *FC* locates the probability of the random event's happening in the class of highest frequency; the *FC* is also the fluctuation-center of frequency in the class-values of the thing-predicted. If every probability-distribution area were exactly bisymmetrical, locating the *FC* would be simply a matter of locating the midpoint of that *R*-class range with the highest probability or *K*, and the more numerous, representative, and accurate the data and the narrower the *R*-class range, the more exactly would such midpoint approximate the real *FC*. But it is the skewness of the probability-distribution, whether a constituent distribution or a probability-resultant, which causes the real difficulty in the location of the real fluctuation-center of probability-values.

In the present investigations on the inheritance of racing capacity in the thoroughbred horse, the location of the *FC* is essential to the determination of the specific probability-values for each of the five-pound stretches of racing capacity expected in the foal as the resultant of several constituent probability-distributions each of which measures the distribution of racing capacity in the foal in reference to a single kinship-factor only.

The *FC* in the probability-resultant is determined as follows:

*Technique by the calculus:*

Given: From the basic manerkonic formula  $M = f(M, R)$ , for the selected racing-capacity value or *M* as a prediction-basis, for each of *n* selected kinships used

$K = K_{fc} \cdot -\frac{(FC \sim R)^2}{2\sigma^2}$ . This is the so-called "manerkonic cross-section," always with an area of 1.00 regardless of its "height" or its "skewness." Observe always the rule  $K_{fc} = \frac{n \text{ or area}}{\sigma \cdot \sqrt{2n}}$ .

Find: *R* = *R*-locus of the Highest Common Probability, i.e., the *FC*.

Procedure: (1) Take the logarithms of the *n* equations above specified, and differentiate.

(2) Add these *n* derivatives, equate to zero, and solve algebraically for *R*.

NOTE: (1) Before adding derivatives, select by grouped observation of "composite curve" or of "summation-values," an approximate *R*-locus for *FC*.



- (2) In each constituent equation, use standard deviation left,  $\sigma_l$ , if  $FC > R$ , or use standard deviation right,  $\sigma_r$ , if  $FC < R$ .

This is the longer and much more intricate method which the practical breeder of the thoroughbred horse is generally unwilling to undertake. The method, however, is mathematically sound and it can apply only to the resultant of several constituent probability-distributions. While other difficulties in computing the probability-resultant are practical debits, this one feature, the fact that several distributions permit the calculus to determine the fluctuation-center, is a technical asset when compared with the single or independent probability-distribution.

#### MANERKONIC ANALYSIS AS A TOOL APPLIED TO INVESTIGATIONS ON THE INHERITANCE OF HUMAN STATURE

Briefly stated, the manerkonic formula reads  $K = f(M, R)$ , which means that the probability  $K$  is a function of the prediction-basis  $M$  and of the thing-predicted  $R$ . Work on the measure and the inheritance of racing capacity in the thoroughbred horse, as given in past reports, developed this formula so that it can now be used as a practical tool for probability-prediction in any case in which  $M$ , the prediction-basis, is an individual unit of the subject-population, which unit is measured accurately for the given subject-quality, and in which  $R$ , the thing-predicted, is a measured quality characteristic of each member of a selected class of individuals of the subject-population, provided that the individuals used in each case constitute a representative sample of the whole population or populations studied. It is found in practice that at least 1000 pairs of  $M, R$  values are needed for successful manerkonic analysis. Of course, the greater the sample-number, the more representative its character, the narrower the prediction-class range, and the more precise the trait-measurement, the sounder will be the resultant prediction-probability. An analysis of this sort may be applied to (1) two sets of associated individuals, each set with a distinct but individually measurable quality; (2) two sets of associated individuals with only one individually measurable quality in common; or (3) one set of individuals with two measurable qualities characteristic of each individual. In every case the cross-section or "slice" of the geometrical manerkonic model at any given  $M$  or prediction-value has an area of 1.00 regardless of its height or flatness or of its skewness right or left. This effect is made possible by converting the numbers for each  $M$ -unit as distributed among its several associated  $R$ -classes from the absolute to the percentage basis.

As contrasted with two-dimensional analysis, this particular three-dimensional or manerkonic analysis has many inherent assets. When the geometric model of a given manerkonic analysis is constructed it presents a mathematical picture in three dimensions which is capable of a great many readings of specifically associated values and of many generalizations. In examining two of these geometrical models, for example one in which the stature of the father is the prediction-basis  $M$  and the stature of the son

is the thing-predicted  $R$ , and a second model in which the stature of the father's father is the prediction-basis  $M$  and stature of the grandson is the thing-predicted  $R$ , one finds that two major criteria readily test the force of the particular  $M$  as a factor in determining the value of the associated  $R$ , and thus test the exactness and quality of the particular prediction. The first criterion is the "diagonalness of the ridge" and the second is its "narrowness and tallness." The more diagonal the ridge and the narrower and taller it is, the more exact and valuable is the prediction which the particular analysis has developed.

#### A SPECIAL APPLICATION OF MANERKONIC ANALYSIS TO THE GENETICS OF HUMAN STATURE

During the year, from the Records of Family Traits in the archives of the Eugenics Record Office, quantitative data on the measured adult height of fourteen different kinds of blood kinships and marital relationships were analyzed by the manerkonic method. These selected kinships and relationships are as follows:

##### A. BLOOD KINSHIPS

- |                          |                                   |
|--------------------------|-----------------------------------|
| 1. Father—adult son      | 7. Father's father—grandchildren  |
| 2. Mother—adult son      | 8. Mother's father—grandchildren  |
| 3. Father—adult daughter | 9. Father's mother—grandchildren  |
| 4. Mother—adult daughter | 10. Mother's mother—grandchildren |
| 5. Brother—brother       | 11. Sister—brother                |
| 6. Sister—sister         | 12. Brother—sister                |

##### B. MATE SELECTION

13. Husband—wife
14. Wife—husband

The accompanying figure, as an example, covers item 3, the Father—adult daughter relationship.

In each of these kinships and relationships, stature in the first named is  $M$  the prediction-basis, and stature in the second is  $R$  the thing-predicted. These associations and measured qualities are coordinated by  $K$  or probability-values.

Each of these blood kinships and marital relationships thus worked out uses one inch of adult stature-range as the class-unit both in  $M$  the prediction-basis and in  $R$  the thing-predicted.

Granted that any given human stature in a child might be associated with any given stature in a father, in a mother, or in any other near blood-kin, still the probability remains that if the kinship which is used as the prediction-basis possesses a definitely measured adult stature, then, all other factors being randomly selected and with sufficient accurate data in hand, it may be readily computed, by the manerkonic technique, by just what probability in the particular population studied the child will, if it survive, develop adult stature within any preselected range.

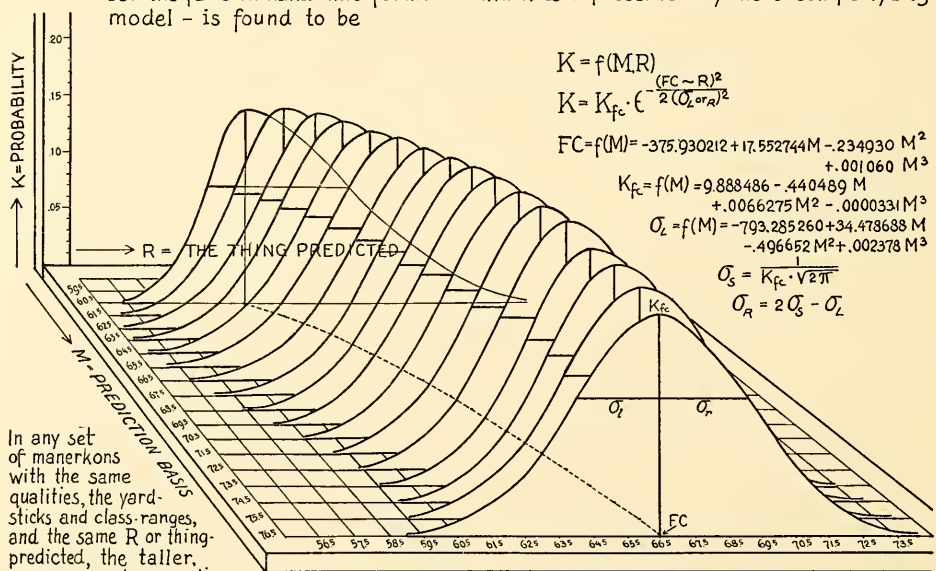
Each manerkonic analysis presents an accurate and easily read mathematical picture of Nature's behavior in associating adult stature in the given specific kinship. The causes of each such specific distribution of

The Manerkon  $K=f(M,R)$  states that  $K$  or probability is a function of (i.e. depends upon)  $M$  or the prediction-basis and  $R$  or the thing-predicted. Whenever any two measurable qualities are represented by a checker-board distribution of individuals  $K=f(M,R)$  may be successfully used in analysis. In any such case either of the two measurable qualities may be arbitrarily selected as  $M$  or the prediction-basis, leaving the other to become  $R$  or the thing-predicted.

In the present example  $M$  = stature of fathers by one inch ranges of height, and  $R$  = stature of their adult daughters by one inch ranges of height. While a father of any selected height might have a daughter of almost any human height, still, for each combination of  $M$  and  $R$ , the immediate task is to find  $K$ , that is the relative frequency, or the probability of occurrence within the particular population under analysis. The present example is based upon the stature-measurements of 3,088 fathers of 4,142 adult daughters in 2,037 American family-stocks, all other kinships and statures and all other factors of whatsoever kind or effect being ignored—being randomly represented.

The immediate task is to find the formula which states mathematically just how and to what extent  $K$  or probability depends upon  $M$  or the stature of the father and upon  $R$  or the associated or dependent stature of the adult daughter

For the facts-in-hand this formula - which is represented by the accompanying model - is found to be



In any set of manerkons with the same qualities, the yard-sticks and class-ranges, and the same  $R$  or thing-predicted, the taller, narrower and more diagonal manerkons indicate the better prediction—that is that the more essential factors have been selected and stressed as  $M$  or the prediction-basis. While the lower, broader and straighter fore-and-aft models mean poorer prediction. Thus,  $K=f(M,R)$  measures accurately how-it-is which is always an essential condition in learning why-it-is thus and so

$$K = f(M, R)$$

$$K = K_{fc} \cdot e^{-\frac{(FC - R)^2}{2(\sigma_L^2 + \sigma_R^2)}}$$

$$FC = f(M) = -375.930212 + 17.552744M - 23.4930M^2 + .001060M^3$$

$$K_{fc} = f(M) = 9.888486 - .440489M + .0066275M^2 - .0000331M^3$$

$$\sigma_L = f(M) = -793.285260 + 34.478638M - .496652M^2 + .002378M^3$$

$$\sigma_S = K_{fc} \cdot \sqrt{2\pi}$$

$$\sigma_A = 2\sigma_S - \sigma_L$$

#### AN EXAMPLE OF THE USE OF MANERKONIC ANALYSIS AS A TOOL IN GENETIC RESEARCH

Father—Adult Daughter Relationship in Stature (Relationship 3 in the Accompanying List)

associated and correlated values remain to be determined by further researches on other aspects of the genetics of human qualities in general and of human stature in particular.

#### EUGENICAL STERILIZATION

Studies were continued on the historical, legal, and biological aspects of eugenical sterilization in the United States. In an analysis of the history of sterilization two dates were found to mark mileposts in the advance which determined, in the United States, the legal basis for sterilization for the prevention of race degeneracy. First, on March 9, 1907, the state of Indiana enacted the first state statute governing the sexual sterilization of a specified class of individuals for the purpose of preventing their reproduction. Second, on May 2, 1927, the Supreme Court of the United States upheld the constitutionality of the Virginia sterilization act. During the twenty years which elapsed between the enactment of the first statute by the state of Indiana and the upholding of the Virginia statute in 1927, twenty-seven different states in all enacted laws governing the sexual sterilization of certain classes of hereditarily handicapped residents of their respective commonwealths. In each of these enactments the state expressed its main motive to be the prevention of reproduction by members of certain definitely specified and proven strains of hereditary defectives or inadequates. Historical analysis shows, however, that the main legal difficulty with many of the earlier statutes was that they were characterized by a tendency to mix the motive of punishment with the motive of race betterment. Many of the earlier state attempts at legislation for the sterilization of certain types of inadequates were held unconstitutional by their respective state courts largely because of the mixed motives of punishment and race betterment. When the law attempted to apply eugenical sterilization specifically to certain groups of legally specified criminalistic, delinquent, or wayward persons without reference to hereditary quality, the courts quite uniformly held such application to constitute a punishment, and such punishment, depending upon the particular case, to constitute such constitutional infractions as a bill of attainder, an *ex post facto* law, two punishments for the same offense, punishment by administrative procedure which did not constitute due process of law, or a cruel or an unusual punishment.

The lessons learned from these experimental statutes and the litigation which followed, were heeded by the legislature of Virginia when it enacted its sterilization statute on March 20, 1924. In this law Virginia eliminated entirely the punitive element and left the biological or race-betterment motive unmixed, and it assured the particular subject the full protection guaranteed by the Bill of Rights and the Constitution of the United States as well as by the constitution of Virginia. With this new statute in operation the Court rules in substance that it is well within the police power of the particular commonwealth to provide, by due process of law which conforms steadfastly with the Bill of Rights, for the sexual sterilization of that nat-



ural class of inhabitants which is made up of persons whose hereditary endowment makes it highly improbable that their offspring would, by the standard set by the particular state, constitute assets to the natural qualities—physical, mental, and spiritual—of the future citizenry of the state, but that such offspring would, on the other hand, owing to defective heredity, most probably fall within some class of the socially inadequate—a defective, dependent, degenerate, or delinquent of some type—or would possess some individual inborn handicap which would render it unable to compete effectively in the struggle for existence or to constitute an asset in the social order.

The compulsory versus the voluntary aspect of eugenical sterilization has been well covered by legislation and litigation, so that it is now a well-established legal principle that any state may, if by due process of law it establishes the hereditary defectiveness of the particular subject, quite lawfully seize such person, if necessary quite contrary to his or her wish, and perform the operation of sexual sterilization upon him or her.

These researches have found that up to the present time the standard of hereditary quality set by the state for the application of eugenical sterilization has been so low biologically that in no case has complaint been brought that in a particular sterilization the state deprived itself of a potential parent of useful future citizens. In this connection there is brought out the necessity for collaboration between the student of human genetics and the legislator. The state needs available a series of definite personal and family-stock records from which it can select its own standard to incorporate into its own statutes, and which selected standard the administrators of the law and the judicial bodies of the state can employ with a common understanding as to its meaning. The state looks to the biologist to supply the genetical criteria for reproductive qualities of a given legal standard for hereditary degeneracy, inadequacy, or handicap and to secure and to evaluate systematic and unimpeachable biological evidence in accordance with such legal standard.

The main fact brought out by the continued research in the field of eugenical sterilization is that legally it is well within the sovereign authority of the people of any one of the several states to set up their own biological standard for their own future citizenry and to move effectively toward such standard.

#### THE SURVEY OF THE HUMAN RESOURCES OF CONNECTICUT

Beginning in October 1936, in a research which will continue in its data-gathering aspect until October 1, 1937, the Eugenics Record Office has been collaborating with the state of Connecticut in a survey of the human resources of that commonwealth. Led by the Commissioner of Public Welfare, Frederic C. Walcott, the preliminary work of the survey was planned in the fall of 1936 and on January 5, 1937, the Honorable Wilbur L. Cross, Governor of the state, appointed the following Commission to Survey the Human Resources of Connecticut: Commissioner Frederic C. Walcott,

chairman, Newton C. Brainard, C. Charles Burlingame, Charles A. Moser, Nathan D. Prince, and Mrs. Sidney Davidson, secretary.

The governor duly instructed this commission to make a thorough survey of the human resources, good and bad, of the state of Connecticut, and particularly to investigate the source, the apparently increasing supply, and the racial, moral, and economic costs of those human inadequates who finally either directly or indirectly become economic charges or moral debits of the state, the county, or the town as persons who, regardless of cause or blame, are: (a) mentally defective, (b) mentally ill, (c) epileptic, (d) criminalistic or antisocial, (e) dependent or pauperous, (f) inebriate or narcotic, (g) blind, deaf, or speech-defective, (h) crippled or deformed, or (i) persons with a naturally weak resistance to some definite constitutional disease.

By agreement between the president of the Carnegie Institution of Washington and the chairman of the Connecticut commission, Harry H. Laughlin, in charge of the Eugenics Record Office of the Institution, was appointed director of this survey. An office and exhibit room were duly opened in the State Office Building at Hartford, and an office and a field staff began work.

#### THE TOWN SURVEY

Up to the end of June 1937, the following studies had been made:

By first-hand investigation within the town, studies for each of the 169 towns were made as follows: The tax rate of the town was determined. The analysis of the town expenditures was made, and both the absolute sum and the percentage of the total town expenditures devoted to the care of the town's inadequate and pauperous population were duly computed. The number and family-stock sources of the town's inadequates and dependents were made the subject of a special study.

#### SPECIAL RESEARCHES

By July 1 the second phase of the survey was well under way. This consisted in assigning special investigators to particular subjects, these main topics being as follows:

(a) The town farms, of which forty-six are in existence. Studies in reference to their cost, their management, and the numbers and quality of the human population being maintained on these several farms with particular reference to causes of their helplessness, whether environmental or constitutional.

(b) The eight county jails and the county homes for children are being studied as of June 1, 1937, for the purpose of finding at first hand the human character of the jail population with particular reference to repeaters and causes of commitment. The county homes for children, which constitute the second type of county institution within the state, are similarly under investigation as to the numbers and classes of their inmates and their sources and natural capacities.

(c) The eighteen state institutions for the several types of socially inadequate and individually handicapped classes are being studied in reference

to the classification of their inmate populations—their sources by towns, their race descent, their citizenship, and their family-stock quality. Their waiting lists and parole lists are being considered in reference to the family stocks and strains represented.

(d) The private institutions and agencies of the state concerned with the socially inadequate are being listed for the first time in systematic form with a view to determining the function and service of each in the field of handling the inadequate and handicapped in the state's population.

(e) The foster and licensed homes similarly are under systematic study in reference to their character and their environmental influence upon the human stock committed to them.

(f) The courts of the state are being systematically studied in reference to the jurisdiction and function of each court as it concerns the care, the control, and commitment or other management of any of the socially inadequate or individually handicapped classes within the state's population.

(g) The non-white blood in the state is the subject of a special survey. These strains are being studied in reference to their origin, numbers, and interracial mixtures and their rates of increase.

(h) Alien blood in Connecticut is the subject of one special study. Past statistical reports and censuses on race-descent and nativity of immigrant stocks in Connecticut are being systematized to tie up with the present survey, and special first-hand studies are being made in a few of the alien centers to determine the quality of recent alien stocks, their relative fertility, and the direction and extent of their interracial matings.

(i) The legal and practical aspects of intercommunity, intercounty, and interstate deportation as a coordinate function of international deportation is undertaken to determine the actual location of responsibility for the care and maintenance of the defective and handicapped classes of the state, together with the definite assessment of costs thereof. Also studies on responsibility for the production or introduction of degenerate or handicapped classes are under way.

(j) A special study is under way with reference to the part which the public schools play in handling the problem of the inadequate classes, especially in city schools which have specialized classes for the backward and the handicapped children.

(k) A reexamination of the Connecticut sterilization law in its legal, biological, and practical aspects constitutes another unit study.

(l) A sample census and registry. A model individual census and population registry card has been designed, and one of the 169 towns of the state has been selected as a "sample town" to find the practicability and the approximate cost per capita of combining a permanent population registry covering personal identification, kinship and biological records with the census enumeration.

The data-gathering aspect of this survey will be completed by October 1 and, by agreement between the Connecticut Commission and the Carnegie Institution of Washington, the director of the survey will undertake the analysis of the facts gathered and the writing of the report.



## ANTHROPOLOGY AND HUMAN GENETICS

*Morris Steggerda and Harriet Cranston*

## GROWTH OF CHILDREN OF DIFFERENT RACES

The work on the physical development of the 400 children of different races has progressed to the stage where standards for seven measurements and ratios are now completed for the Maya and Navajo Indians, Dutch whites, and American Negroes. Individual growth curves are being plotted for comparison with these standards. The Maya and Dutch children have been measured for the past seven years.

*Bacillus acidophilus* AMONG THE YUCATAN MAYA

A report by Steggerda and Hill (see Bibliography) showed a low incidence of dental caries in the mouths of Maya Indians. The present study is an attempt to determine the prevalence of *Bacillus acidophilus* in the mouths of these people and if possible to correlate the number of bacteria found with the incidence of caries. One hundred and eighty individuals were studied. One beef broth and two agar plate cultures were made from the saliva of each individual. One beef broth culture, pH 5, was used to determine the presence or absence of *B. acidophilus*, and two agar plate cultures, pH 5.1, were used to determine the relative numbers of these organisms per cubic centimeter of saliva.

The results showed that the percentage of Indians free from *B. acidophilus* was higher and the number of *B. acidophilus* in individual mouths was relatively lower than for whites in the United States.

These results support the theory that the direct cause of dental caries is the decalcification of the teeth by acids produced by the presence of *B. acidophilus*. Because the diet of the Maya Indians is largely carbohydrate and one which should not deter the growth of these organisms, the results strongly support the suggestion by Steggerda and Hill that resistance to dental caries, i.e. a factor which limits the growth of *B. acidophilus*, may be a racial characteristic.

## TESTING THE PSYCHOLOGY OF RACES

While the psychology tests which are available today are fairly adequate for testing within a given group, they are not satisfactory when racial comparisons are desired. Realizing these difficulties, the author and his assistants have designed a rating scale, involving 61 mental attributes. This scale was submitted to white people who are acquainted with Maya Indians in Yucatan and to another white group acquainted with Navajos of Arizona. They were asked to grade the scale, thus giving their opinion of the members of that particular group. The resulting description of the two racial groups was of interest since the opinions in most cases were quite definite. In many of the traits, the combined ratings for the Navajos were different from those for the Maya, indicating a decided mental makeup or cultural pattern. With the aid of this scale we believe that we have been able to describe more or less objectively the Yucatan Maya, as a race of clean, thrifty, and conservative people. In contrast to the Navajo Indians they are quick, active, alert, polite, and expressive. They have a practical sense of humor; their sex be-



havior is not overemphasized; they have a tendency to excessive alcoholism. Toward strangers they are kindly, and among themselves they are sociable.

A modification of the McAdory Art Test was also designed by the author and his associates, in which horses, cows, trees, clouds, and other natural objects replaced the dresses, fences, silverware, automobiles, etc. of the McAdory Art Test. The subject was presented with a plate of four pictures and asked to select the one he liked best, second best, third best, and least, and then asked why he had chosen those he liked best and least. The test was given to Navajo Indians in Arizona and to Dutch whites in Michigan, with the immediate result that the Navajos judged all the objects from a utilitarian standpoint, while the whites judged them more from the point of view of art. With further refinement the test may have possibilities of determining phases of culture.

Dr. E. F. Kinder, psychologist at Letchworth Village, is continuing the cooperative study relative to the Goodenough Drawing Scale as applied to various human races. Dr. M. W. Curti, psychologist at Smith College, co-operates also by adapting and analyzing the Minnesota Pre-School Scale as applied to Maya babies. Neither of these studies has advanced far enough for publication of results. Theodora M. Abel's test, calling for a design using 19 straight lines and 6 curved to be placed in a rectangle, was given by the author to both Navajos and Dutch whites. Dr. Abel finds that the majority of Navajo designs are characteristic of a cultural pattern that is unlike that of the Apache Indians and of the various groups of whites studied. The designs of the Dutch white group showed no distinct culture but were similar to those of mixed nationalities in New York high schools. Sixty-one per cent of the Dutch whites as compared with 50 per cent of the New York high school group made complicated designs of geometric patterns.

A Form Discrimination Test designed by Dr. C. B. Davenport, consisting of pairs of circles, octagons, and triangles, one of which is perfect and the other varying in degree of imperfection, was submitted to the Negroes, whites, and Indians, with the general conclusion that most races increase in ability with age. Navajo males, however, and one age group of Navajo females decrease in ability with age. It is thought that this result may be due in part to the prevalence of trachoma among them.

#### FACTS LEARNED FROM A STUDY OF YUCATAN AGRICULTURE

1. The average size of Yucatan cornfields, based upon figures given by the farmers, representing 638 individual fields, is 9.8 acres.
2. One hundred ninety man-days are spent each year to produce the corn on an average plot. Of these, 48 days are spent producing the corn necessary for an average family of five; 24 days for an average amount of stock; and 118 days for corn to sell for cash.
3. Yields of first-year *milpas* are approximately 1.66 bushels per *mecate* or 16.8 bushels per acre.
4. Second-year *milpas* yield approximately three-quarters as much as first-year *milpas*.
5. The yield of an experimental *mecate* farmed in Maya style dropped each year in the following order: from 71 to 61, to 36, to 15 pounds.

## FAMILY STATISTICS

Additional data have been secured concerning family statistics, both for Piste and for Pencuyut. For the latter village, pedigrees were made from the town records of the past thirty-five years, and the figures given for Pencuyut were obtained from these pedigrees.

*Age of women at marriage and at birth of first child*

	No. cases	Mean age at marriage	No. cases	Mean age at birth of first child
Piste.....	15	16.03 $\pm$ 0.28	33	18.2 $\pm$ 0.22
Pencuyut.....	21	17.4 $\pm$ 0.34	24	18.5 $\pm$ 0.35
Both.....	36	16.8 $\pm$ 0.24	57	18.3 $\pm$ 0.19

It will be noted that more than a year elapses between marriage and the birth of the first child. The average interval, for 73 cases, is 16.7 months. Of these cases we have the birth and marriage dates for 24; 13 were married between 13 and 16 years of age, and 11 between 17 and 23. The average interval between marriage and the first baby for the younger mothers was 15.5 months, whereas for the older mothers it was 17.8 months.

We have 580 cases in which we know the exact interval between consecutive births, the average of which is 27.34 months. Since there is no knowledge of contraception among these Indians, this interval of more than two years between children indicates Nature's regulatory mechanism for controlling human reproduction.

In the records for Piste and Pencuyut, there were 47 women whose reproductive life was apparently complete. The mean number of children per woman was 8.14 $\pm$ 0.27. Of these 47 women, there were 39 for whom we have birth dates of the first and last child. The mean length of reproductive life was 16.65 $\pm$ 0.43 years.

The mean age at marriage for 25 men of both towns is 21.5 $\pm$ 0.33.

NUTRITION LABORATORY<sup>1</sup>

FRANCIS G. BENEDICT, DIRECTOR

In this the last report of the Director of the Nutrition Laboratory it would be fitting to comment *in extenso* on the work of the Laboratory during the three decades that it has been in operation. The story in full is told, however, in 32 monographs and 412 scientific papers. Many of the broader problems impending at the inception of the Laboratory have been completed, or at least sufficiently completed to justify leaving further studies on those particular lines to other individuals or institutes. The obligation of an institution of this kind to blaze trails as well as to accumulate definitive scientific data on salient points is only too obvious.

It has been necessary to spend a large amount of time, many of us feel an undue amount of time, in the development of the peculiar techniques required for our general lines of attack. Fortunately we are now able to leave these elaborate techniques and present extremely simple forms that are rapidly being introduced into other laboratories.

With the completion of certain of the earlier problems, however, there has been a revealing or development of a large number of other problems from which only those most likely to contribute to a general betterment of human values should be selected. It is thus obvious that the usefulness of the Laboratory is by no means approaching an end. Astronomical research is literally without limits; research on man is equally unfixed in limits.

A study of the physiology and psychology of man by reference to similar studies on animals has been a most fruitful field of research for years. The abnormal in man is often normal in the animal and an understanding of the true nature of the normal process is imperatively needed in interpreting the abnormal manifestation. Some of these problems are so salient that the writer feels justified in stressing their importance along with the high degree of probably successful attack by methods developed in the Nutrition Laboratory. With no group of animals have there been any greater possibilities of results of specific value to man than with domestic livestock. Comprehensive studies on such animals have been pursued, in collaboration with Professor E. G. Ritzman, at the University of New Hampshire, where our technical methods of attack are particularly needed on a considerable number of pressing problems in the physiology and in the economic life of ruminants and horses in their associations with and relations to man. Active preparations are going on for furthering this research, and the absolute certainty of securing valuable and important results makes such a research thoroughly justifiable.

With humans and with animals one of the larger problems necessitating direct calorimetric measurements, that is, the establishment of the caloric value of oxygen and carbon dioxide at respiratory quotients not only between 0.70 and 1.00 but considerably above 1.00, has been so far solved that we believe there is little, if anything, remaining to be gained in most investigations by further use of direct calorimetry. In problems dealing with gaseous metabolism, however, the situation is quite different. The studies

<sup>1</sup> Situated in Boston, Massachusetts.

in comparative physiology have brought out strikingly the physiological, the pathological, and undoubtedly the therapeutic importance of knowing the amount and variation of the carbohydrate reserve in the body, the influence of depletion of this reserve, and with humans the conditions that affect its storage, its amount, the rate at which it is drawn upon, and the rapidity with which it is refilled. Although little has been done on this basic problem, fortunately the technique of today permits perhaps for the first time precise measurements of this reserve.

#### COOPERATING AND VISITING INVESTIGATORS

Professor E. G. Ritzman, of the Laboratory for Animal Nutrition at the University of New Hampshire, has actively cooperated in the important investigation on the metabolism of large domestic animals which has been in progress for a number of years.

Dr. Priscilla White, of the Joslin Clinic and the New England Deaconess Hospital, Boston, has continued her interest in the cooperative study of a helium-oxygen mixture for the prevention of respiratory failure in newborn infants of diabetic mothers, and Dr. Howard F. Root, of the same institution, has carried out further studies of the metabolism in diabetic coma.

Dr. G. L. Streeter, Director of the Department of Embryology at Baltimore, in cooperation with Dr. T. M. Carpenter, of the Nutrition Laboratory, and Dr. C. G. Hartman, of Baltimore, has continued the study of the *Macacus rhesus* colony at his department.

Professor H. C. Sherman, of the Department of Chemistry at Columbia University, brought to an end his cooperative investigation on the metabolic effect of old age and exercise upon the rat.

Dr. Morris Steggerda, of the Department of Genetics at Cold Spring Harbor, spent some time at the Nutrition Laboratory refreshing his metabolism technique prior to a cooperative study of the Navajo Indian in New Mexico.

Dr. Milton O. Lee, of the Memorial Foundation for Neuro-Endocrine Research at the Harvard Medical School, has given his invaluable assistance in connection with many of our problems and is completing the research on avian thyroidectomy.

Of the many visits of scientists to the Nutrition Laboratory during the year, special mention is made of that of Professor Walter R. Miles, of the Institute of Human Relations at Yale University. Professor Miles's stimulating association with the Laboratory has continued for over two decades.

Professor and Mrs. August Krogh, of the Laboratory of Zoophysiology, University of Copenhagen, and Dr. Gustav Nylin, of Stockholm, represented our annual contact with the intensive Scandinavian physiologists.

Members of the Division of Animal Biology of the Carnegie Institution of Washington who were present at a meeting at the Nutrition Laboratory on January 9, 1937, were F. G. Benedict, A. F. Blakeslee, T. M. Carpenter, C. G. Hartman, R. C. Lee, E. C. MacDowell, O. Riddle, and G. L. Streeter. Guests were D. H. Tennent, of Bryn Mawr, E. G. Ritzman, of the Laboratory for Animal Nutrition at Durham, New Hampshire, M. O. Lee and G. B. Wislocki, of the Harvard Medical School, and Priscilla White, of the



Deaconess Hospital. Local speakers presented papers dealing with the recent investigations of the Nutrition Laboratory and its collaborators. From these papers it was evident that there are many salient problems, problems peculiar to Nutrition Laboratory techniques, needing immediate attack.

### LECTURES

A paper on "The constancy of the atmosphere with respect to its carbon dioxide and oxygen content" was given by Dr. T. M. Carpenter, September 10, 1936, at the meeting of the American Chemical Society in Pittsburgh, Pennsylvania. A paper on "The metabolism of alcohol in the animal body" was given by him on January 19, 1937, at the Carnegie Institution of Washington; on January 20 at the Department of Pharmacology, Johns Hopkins University Medical School; and on January 21 at the Journal Club meeting of the Department of Genetics, Cold Spring Harbor, New York. On March 12 he addressed the Northeastern Section of the American Chemical Society at Boston on "The metabolism of alcohol." On March 13 he lectured to the students in the course in biochemistry at the Harvard Medical School on "Basal metabolism and specific dynamic action." On April 21 he presented a paper on "The lactic acid in human blood in relation to the respiratory quotient after the ingestion of hexoses" at the meeting of the American Institute of Nutrition at Memphis, Tennessee.

Interest in the Nutrition Laboratory's comprehensive study of the elephant continued, and lectures on the physiology of the elephant were given by the Director as follows: on August 21, 1936, before the Washington County Medical Society at Calais, Maine; on November 12, 1936, before the New York Academy of Medicine; and on January 18, 1937, before the Boston University Medical Society. A paper entitled "Race: a factor in human metabolism" was presented by the Director before the American Philosophical Society on April 23, 1937, and one entitled "Body fat as a factor in heat production" before the National Academy of Sciences on April 26, 1937.

### INVESTIGATIONS IN PROGRESS

*The respiratory exchange, alveolar air, and blood lactic acid of man after the ingestion of hexoses*—The investigation on the effect of hexoses on the lactic acid content of human blood in relation to the alveolar carbon dioxide and respiratory quotient, which was begun last year by Dr. T. M. Carpenter with the cooperation of Drs. E. H. Bensley, D. B. Dill, and H. T. Edwards, has been completed and a preliminary report of the results has been presented.

*Metabolism studies on the Macacus rhesus*—The metabolism measurements on the *Macacus rhesus* have been continued with special reference to effect of seasonal and temperature variation. The metabolism of young animals has also been determined. The investigation has been carried on by Dr. T. M. Carpenter, with the cooperation of Dr. George L. Streeter and Dr. Carl G. Hartman, and with the technical assistance of K. Koudelka, in the Department of Embryology at Baltimore.

*Metabolism in diabetic coma*—In cooperation with Dr. Howard F. Root, of the New England Deaconess Hospital, the metabolism of patients in diabetic coma has been determined as opportunity has offered by means of

the portable helmet respiration apparatus of the Nutrition Laboratory. The measurements have been made by Dr. T. M. Carpenter, with the assistance of R. C. Lee and B. James.

*Studies of hygrometric and gasometric techniques*—A systematic study has begun on the conditions affecting the accuracy of the water vapor determinations by the ordinary psychrometer. The accuracy of the Fox bag method for proportional sampling of the ventilating air currents of respiration apparatus has been reinvestigated. In these studies Dr. T. M. Carpenter has had the assistance of B. James and A. J. Murphy.

*Alcohol in expired air*—A procedure for the determination of alcohol in human expired air has been developed. It has been applied for the study of the retention of alcohol in the mucous membranes of the mouth in relation to the ingestion of alcohol-containing liquids and is also to be used as a criterion in the determination of the rapidity of the disappearance of alcohol in the human body after the drinking of different concentrations and quantities of alcohol. Dr. T. M. Carpenter has been assisted by A. J. Murphy in these determinations.

*The effect of urea on the respiratory exchange of man*—It has been found by other investigators that the carbon-dioxide content of human blood is altered by the ingestion of urea. To determine whether the respiratory quotient would be altered in this condition, determinations of the respiratory exchange and alveolar carbon dioxide following the ingestion of 20 to 40 gm. of urea were made with special apparatus. A urine study correlated the excretion of urea with the changes in respiratory exchange and alveolar carbon dioxide. This study has been conducted by Dr. T. M. Carpenter with the assistance of B. James and R. E. Murray.

*Direct calorimetry with geese*—Direct calorimetry, especially with respiratory quotients above 1.00, was thought to be a very important aid in establishing the possible variations in the caloric value of oxygen under conditions where there was a large transformation of carbohydrate into fat. The fact that the differential method was necessary here, in that the animal was studied under normal conditions and then with excess feeding, and the fact that it was necessary to separate the oxidative processes and the lipogenetic processes, especially with reference to the energy relations, called for the most precise control of the accuracy of the calorimetric and gasometric methods employed. This investigation was, in large part, in the hands of R. C. Lee. The intricate technical construction necessary was in the hands of V. Coropatchinsky, the gas analysis in the hands of G. Lee, and the care of the animals in the hands of C. Hatch. As a result of the investigation it has been concluded that the method of indirect calorimetry, i.e., calculation of the heat production from the gaseous metabolism, is extremely accurate even under conditions when the respiratory quotient is considerably above 1.00, and consequently the time-consuming, expensive direct calorimetry, as such, is no longer to be seriously considered on the Nutrition Laboratory program.

*Metabolism of the marmot*—The investigation on the marmot (woodchuck), which has been in progress since 1931, has been continued on a colony of twenty-five animals. Studies have been made of the heat produc-

tion of this animal during hibernation and in the transitory stages of going into and awaking from hibernation. Additional data on its metabolism in the zone of thermic neutrality when not hibernating and on its metabolic reaction to cold were also obtained. Studies of the heart rate, respiration rate, and rectal temperature, with special reference to their relationship to the metabolism, were carried out during both the hibernating and nonhibernating states. Some critical studies were made in which hibernation was induced either by carbon dioxide or by nembutal narcosis. These observations have been made by R. C. Lee, assisted by G. Lee and C. Hatch.

*Observations on the elephant*—To investigate further our unusual finding with the elephant of a higher heart rate when lying than when standing, a few observations were carried out in the spring of 1937. At the same time special effort was made to secure samples of rectal gases to analyze for methane content. These observations were carried out with the assistance of R. C. Lee and H. B. Lee.

*Metabolism of large domestic animals*—Our most profitable cooperative studies with Professor E. G. Ritzman at the University of New Hampshire have continued during the past year. Experiments have centered almost entirely on the relatively little-explored subject of the effect of environmental temperature on the basal metabolism and on the character and the amount of the insensible perspiration of the various species of farm livestock, predominantly the ruminant. A series of experiments with an adult Chester pig to determine any possible seasonal influences on its metabolism was begun. Further investigation of the treadmill plan (referred to in last year's report) to measure the metabolism of the horse in action led to the development of an optional method of using a mask for this purpose. A special type of mask has been designed and is well along toward completion. In these researches Professor Ritzman has been assisted by N. F. Colovos, H. H. Latimer, R. Doe, and A. D. Littlehale.

*Prevention of respiratory failure in newborn infants*—The Nutrition Laboratory has continued to cooperate with Dr. Priscilla White, of the Joslin Clinic and the New England Deaconess Hospital, in the use of a respiration apparatus designed to administer a mixture of oxygen and helium for the prevention of respiratory failure of newborn infants of diabetic mothers. R. C. Lee and H. B. Lee have assisted in this study.

*Metabolism of the rabbit*—Further research on the rabbit, which lends itself so well to a study of heat production as influenced by differences in size (weight) within the same species, has been continued. Emphasis has been laid upon the metabolism during the first days of fasting to note when the post-absorptive condition is reached, the establishment of the zone of thermic neutrality for the rabbit, and the animal's reaction to different environmental temperatures. These experiments have been supplemented by a study of the insensible perspiration, heart rate, respiration rate, and body temperature. R. C. Lee has conducted this research, assisted by G. Lee and C. Hatch.

#### EDITORIAL AND LITERARY WORK

A monograph on "Lipogenesis in the animal body, with special reference to the physiology of the goose," with the collaboration of R. C. Lee, is now



in the printer's hands. Several articles have also been written and either have been accepted or are ready to be submitted for publication. These are:

Race: A factor in human metabolism. (F. G. Benedict. Proceedings of the American Philosophical Society.)

Body fat as a factor in heat production. (F. G. Benedict and R. C. Lee. Biochemische Zeitschrift.)

Basal metabolism of rats in relation to old age and exercise during old age. (F. G. Benedict and H. C. Sherman. Journal of Nutrition.)

Effect of thyroidectomy and thyroid feeding in geese on the basal metabolism at different temperatures. (M. O. Lee and R. C. Lee. Endocrinology.)

The basal metabolism and urinary nitrogen excretion of Orientals in Peiping, China. (F. G. Benedict, L. C. Kung, and S. D. Wilson. Chinese Journal of Physiology.)

Comparison of the basal metabolism of the Chinese in Szechwan during waking and sleeping states. (L. G. Kilborn and F. G. Benedict. Chinese Journal of Physiology.)

In addition, we are actively engaged in the preparation of three monographs: one in cooperation with Professor E. G. Ritzman on "Nutritional physiology of the ruminant with special reference to energy"; a second, on the metabolism of the hibernating marmot, with the cooperation of R. C. Lee; and a third on interspecific metabolism studies.

Dr. Blanche B. Daly has continued her association with the Nutrition Laboratory as *littérateur*. The large mass of editorial work has had the critical supervision of the editor, Elsie A. Wilson.

#### PUBLICATIONS

- (1) *The constancy of the atmosphere with respect to carbon dioxide and oxygen content.* Thorne M. Carpenter. Jour. Amer. Chem. Soc., vol. 59, 358-360 (1937).

The grand average of three series of analyses of outdoor air, 75 at Durham, New Hampshire, 790 at Baltimore, and 291 at Boston, gave 0.031 per cent for carbon dioxide and 20.939 per cent for oxygen. In spite of the widely different local conditions of the three laboratories there was no evidence that variations in season or proximity of large consumers of fuel caused any measurable differences in carbon dioxide and oxygen content of atmospheric air.

- (2) *The metabolism of alcohol.* Thorne M. Carpenter. Nucleus, vol. 14, 159 (1937).

Abstract of lecture. (See page 78.)

- (3) *The effect of galactose on the human respiratory quotient and alveolar carbon dioxide.* Thorne M. Carpenter. Jour. Nutrition, vol. 13, 583-600 (1937).

In these experiments on a human subject with galactose there was a fall in the alveolar carbon dioxide accompanying rises in the respiratory quotient. Significant correlation coefficients between the respiratory quotient and the alveolar carbon dioxide were found. The results indicate that part of the rise in respiratory quotient after the ingestion of galactose must be due to the elimination of extra carbon dioxide in the lowering of the carbon dioxide content of the alveolar air. Presumably the cause is the formation of organic acids in the intermediary metabolism of galactose.

- (4) *The lactic acid in human blood in relation to the respiratory quotient after the ingestion of hexoses.* T. M. Carpenter, E. H. Bensley, D. B. Dill, and H. T. Edwards. Jour. Nutrition, vol. 13, supplement, p. 15 (1937).

Abstract. (See page 78.)



- (5) *The effect of galactose on the metabolism of ethyl alcohol in man.* Thorne M. Carpenter and Robert C. Lee. Jour. Pharmacol. and Exper. Therap., vol. 60, 254-263 (1937).

Experiments were made with 46.5 gm. of galactose with or without the addition of 15 cc. of alcohol in the same manner as in the two preceding studies. The duration of alcohol in the expired air was even longer with ingestion of galactose than with alcohol alone. The amount of carbohydrate metabolized was practically the same in the two groups of experiments with galactose, but there was a marked decrease in the metabolism of fat when alcohol was combined with galactose. Alcohol furnished about 36 per cent of the total energy output and is not metabolized as rapidly when ingested with galactose as with glucose or fructose. The most striking finding was the markedly increased elimination of sugar in the urine when alcohol was added to the galactose over that found when galactose alone was taken. It is suggested that this was due to the more rapid absorption of galactose when accompanied by alcohol.

- (6) *The effect of glucose on the metabolism of ethyl alcohol in man.* Thorne M. Carpenter and Robert C. Lee. Jour. Pharmacol. and Exper. Therap., vol. 60, 264-285 (1937).

The respiratory exchange and alcohol in expired air were determined for 3 or 3.75 hours after the ingestion of 10, 15, and 20 cc. of alcohol alone and after the ingestion of the same amounts of alcohol with the addition of 31, 46.5, and 62 gm. of glucose. The addition of glucose definitely shortened the time during which alcohol was found in expired air. When alcohol alone or alcohol and glucose were given, there was a marked decrease in the amount of fat metabolized. The ingestion of either glucose or alcohol caused a rise in the heat production, and there was a summation of the separate increases when the two were given together. On the basis of total duration of the experiments, alcohol furnished 25 to 38 per cent of the total heat production, but on the basis of the duration of alcohol in the expired air, the percentage ranged from 44 to 75. The latter finding suggests very strongly that the disappearance of alcohol is not due to actual combustion alone but to a transformation into some other substance.

- (7) *The effect of fructose on the metabolism of ethyl alcohol in man.* Thorne M. Carpenter and Robert C. Lee. Jour. Pharmacol. and Exper. Therap., vol. 60, 286-295 (1937).

Alcohol disappeared from the expired air one-half hour earlier with fructose than with glucose. Calculation of the materials metabolized showed that alcohol and fructose caused a more marked lowering in the metabolism of fat than fructose alone. The ingestion of fructose or fructose and alcohol caused an increase in the heat production with a summation of the increases after fructose alone and alcohol alone when they were given together. With 15 cc. of alcohol and 46.5 gm. of fructose the rise in heat production equaled nearly 7 per cent of the energy value of the materials. As in the preceding investigation, when the percentage of the heat output due to alcohol is calculated on the duration of it in the expired air, the percentages are so large as to render questionable the assumption that the alcohol disappears by combustion alone.

- (8) *The metabolism of alcohol in the animal body.* Thorne M. Carpenter. Scientific Monthly, vol. 45, 5-18 (1937).

This lecture gives a survey of the principal investigations on the metabolism of alcohol that have been made since a plan for the study of the physiological and psychological effects of alcohol was proposed by the Nutrition Laboratory in 1913. The properties of alcohol as a suitable substance for metabolic study are discussed, and examples are given of the course of alcohol in expired air, urine, and blood after the ingestion of alcohol. The studies on the distribution in various tissues, of the effect of muscular work on the disappearance of alcohol, and of the metabolic result

of giving alcohol with and without the addition of glucose, fructose, or galactose are described. The conclusion is drawn that alcohol either replaces fat in metabolism or is converted into a substance with a respiratory quotient near that of fat. It is suggested that future investigations on the metabolism of alcohol would be profitable under those conditions in which the metabolism of alcohol is accelerated.

- (9) *Necrology of Lafayette Benedict Mendel (1872-1935)*. Francis G. Benedict. Proc. Amer. Philos. Soc., vol. 76, 394 (1936).
- (10) *A stack of constant volume for respiration experiments with humans*. Francis G. Benedict. Jour. Biol. Chem., vol. 116, 307-320 (1936).

An open-circuit respiration apparatus is described, the chief feature of which is an inexpensive chamber (an elongated pipe or stack) of constant volume for the collection of expired air. The principle of the apparatus rests upon the stratification of the expired air at the bottom of the stack. Alcohol and physiological control tests have proved that the apparatus functions accurately to within the slight error inherent in gas analysis by the Haldane method.

- (11) *The respiratory metabolism of the chimpanzee*. John M. Bruhn and Francis G. Benedict. Proc. Amer. Acad. Arts and Sci., vol. 71, 259-326 (1936).

Measurements were made of the basal metabolism of 22 chimpanzees ranging in weight from 3 to 50 kg. and in age from 2 months to 15 years, including both sexes. The variability in the basal metabolism from day to day or week to week was greater than that to be expected with well-conditioned humans. Season and sex had no sharply defined effects. Menstruation had a variable effect. The total heat production increased continually from youth to adult age. The heat production per kilogram of body weight was higher, the younger and smaller the chimpanzee. The heat production per  $10w^{2/3}$  was, however, fairly uniform at all the weights and ages studied. The 24-hour basal heat production of the adult chimpanzee, is, on the average, 980 calories per two-thirds power of the body weight times 10.

- (12) *La production de chaleur de la souris. Étude de plusieurs races de souris*. Francis G. Benedict and Robert C. Lee. Ann. de physiol., vol. 12, 983-1064 (1936).

Studies were made of four races of mice, white, fat, dwarf, and wild, having average weights of 21, 57, 8, and 19 gm., respectively. The *minimum* heat production per kilogram per 24 hours was: white mouse, 135 calories; fat mouse, 110 calories; dwarf mouse, 110 calories; wild mouse, 160 calories. The average length of life of mice fasting until death (at thermic neutrality) was: white, 5 days; fat, 9 days; dwarf, 9 days; wild, 4 days. The losses in weight were 37, 35, 46, and 29 per cent, respectively. Analyses were made of the chemical composition of the bodies of white, fat, and dwarf mice and comparisons made of the relationships between their metabolic levels and physical and chemical characteristics. The 24-hour basal heat production per  $9w^{2/3}$  is extraordinarily low with the mouse, the potential minimum values ranging from 250 calories with the dwarf mouse (the lowest value ever recorded for a warm-blooded animal) to 475 calories with the fat mouse, or only about one-half the conventional 1,000 calories ascribed to all warm-blooded animals.

- (13) *The basal metabolism of Chinese in Szechwan*. L. G. Kilborn and F. G. Benedict. Chinese Jour. Physiol., vol. 11, 107-126 (1937).

The basal metabolism of 54 Chinese males, 14 Chinese females, and 26 Anglo-Saxons (5 males and 21 females), living in Szechwan, was determined with the field metabolism apparatus. They showed a basal metabolism differing but little from that of Westerners living in the same region. The factors possibly responsible for these results, which differ from most recorded results for Chinese living elsewhere, are discussed.

- (14) *The basal metabolism of the Miao race of Kweichow.* L. G. Kilborn and F. G. Benedict. Chinese Jour. Physiol., vol. 11, 127-134 (1937).

The basal metabolism of 23 male Hwa Miao and one male Chwan Miao was determined with the field metabolism apparatus. The average deviation from the Harris-Benedict standard was +15.8 per cent. The average pulse rate was 55 per minute. The Miao are the only Asiatic race so far reported with a basal metabolic rate higher than the Occidental standard.

- (15) *Necrology of Lafayette Benedict Mendel (1872-1935).* Francis G. Benedict. Proc. Amer. Acad. Arts and Sci., vol. 71, 527-528 (1937).

- (16) *Basal metabolism of normal young men and women of various races in Hawaii.* C. D. Miller and F. G. Benedict. Univ. Hawaii, Research Pub. No. 15, 1-60 (1937).

With the field respiration apparatus the basal metabolism of 258 normal men and women of mixed races in Hawaii has been determined. The greatest average deviation was found for the Chinese women (-15.0 per cent), and for the Chinese-Hawaiian women it was -13.7 per cent. For all other groups, male and female, the average deviation was -10 per cent or less, the smallest deviation being -2.4 per cent for the Chinese-Hawaiian men. There is little evidence that the metabolism is affected by climate or diet, and only with the women is there strong proof of a racial factor influencing the basal metabolism.

- (17) *Basal metabolism of Samoan men.* C. D. Miller and F. G. Benedict. Univ. Hawaii, Research Pub. No. 15, 61-71 (1937).

Twenty-one men of pure Polynesian ancestry, who were born and had lived in Samoa all their lives, served as subjects. Their average age was 25 years, their weight 73.9 kg., and their height 175 cm. Their metabolism was essentially the same as the Harris-Benedict prediction standard (on the average, -1.2 per cent) but definitely higher than that of Caucasian men and other racial groups living in Hawaii, although the climate of Samoa is distinctly tropical as compared with the semitropical climate of Hawaii. These results give evidence of the existence of a racial factor in metabolism.



**TORTUGAS LABORATORY**

D. H. TENNENT, EXECUTIVE OFFICER

During the past year the Tortugas Laboratory suffered a serious loss in the death of its Executive Officer, Dr. William H. Longley. Long associated with Dr. Alfred G. Mayor, the founder of the Laboratory, Dr. Longley upheld Dr. Mayor's ideals, gave to the Laboratory unselfish devotion, and met with enthusiasm the changing demands of marine biological research. Under his care the Laboratory developed steadily.

During the summer of 1937 the Tortugas Laboratory was open from June 3 to August 10. Mr. John W. Mills, chief engineer, remained in charge of all equipment. A new 3-kw. 110-volt Kohler generator, installed at the beginning of the season, gave a thoroughly satisfactory supply of steady current. The new generator replaces an old 1-kw. generator and with the old storage battery equipment adequately supplies all needs for both AC and DC current. Various minor improvements made it possible to take care of an increased number of physiological investigations. Through a grant by the National Research Council the laboratory was again supplied with 110 mgm. of radium for use throughout the season.

The spirited cooperation of every member of the Laboratory community resulted in a season of fine productive activity. The plant was left in excellent physical condition.

The following investigators studied at the Laboratory during the season:

- F. J. Brinley, North Dakota Agricultural College. Studies on the implantation of embryonic fish tissue. June 3 to August 10.
- Robert Chambers, Washington Square College, New York University. The coalescence of sea urchin eggs with oil drops. June 3 to June 29.
- Leonard B. Clark, Union College. Studies on the swarming of the Atlantic palolo. July 2 to August 10.
- Paul R. Cutright, Beaver College. Studies on the development of the dorsal spine in the sting ray. July 15 to August 10.
- Hugh H. Darby, College of Physicians and Surgeons, Columbia University. Continuation of studies on the development of the chela in Crustacea in relation to gamma radiation; extraction of vitamin D-like substance from seaweeds. June 3 to August 10.
- John H. Davis Jr., Southwestern College. The rôle of mangroves in building new land areas. July 2 to July 13.
- John E. Harris, Cambridge University. Hydrodynamical problems of fin motion in fishes. June 3 to July 27.
- Norris Jones, Swarthmore College. Investigations on ascidians. July 2 to July 27.
- Frank R. Kille, Swarthmore College. Regeneration in holothurians. June 17 to July 27.
- M. J. Kopac, Washington Square College, New York University. Oil-cytoplasm interfacial tensions and tensions at cut surfaces. June 17 to July 13.
- Marius Le Compte, Royal Museum of Natural History, Brussels. General collecting and studies on coral reefs. July 15 to August 10.
- Balduin Lucké, University of Pennsylvania Medical School. Studies on tumors in fishes. June 3 to July 13.
- Gordon Marsh, State University of Iowa. Electromotive force in *Valonia*. June 3 to August 10.



Harold H. Plough, Amherst College. Investigations on ascidians. July 2 to August 10.  
Philip Powers, University of Pennsylvania. Studies of the ciliates of sea urchins.  
June 17 to July 27.

F. C. Steward, Birkbeck College, University of London. Further investigations on the physiology of *Valonia*. June 17 to August 10.

D. H. Tennent, Bryn Mawr College. Photodynamic effects of vital dyes. June 3 to August 10.

Messrs. Edward Chambers, Princeton University; J. A. Harrison, University of London; G. A. Streeter, Yale University; and D. M. Tennent, Yale University, were scientific assistants in certain investigations from June 17 to August 10.

*Studies on the Implantation of Embryonic Fish Tissue, with Notes on the Spawning Habits and Development of Four Species of Fishes,*  
by Floyd J. Brinley

During the course of the investigation, 89 whole livers, exclusive of the gall bladder, and 97 spleens were removed from embryos of the hardhead shiner, from 6 to 8 days after fertilization, and implanted into the yolk sac of other embryos of the same age. No apparent effect on the host was noticed and gross examination indicated that there was considerable development of the implant. A number of these embryos were fixed at various intervals after implantation and are to be sectioned and studied during the winter.

Spawning of the hardhead shiner occurred from June 18 until the closing of the Laboratory. Eggs could be collected either by stripping the ripe adults or by placing them in a specially constructed live box containing cheese-cloth trays and allowing the fish to spawn naturally. Spawning occurs between midnight and 7 a. m. Development is fairly rapid, and the eggs hatch on the eighth day. The mortality of the newly hatched larvæ is very high, and floating trays were used to keep as many of them alive as possible.

*Pomacentrus* eggs were collected in large numbers in old conch shells from June 15 until the closing of the Laboratory. Eggs are guarded by the male; from one to three females may lay in the same shell at different times, and all eggs are apparently fertilized by the same male.

Eggs of slippery dick and a small parrot fish were obtained by stripping the adults from June 10 through July.

Some preliminary experiments were conducted on the action of certain drugs on the innervated and nervated heart of the embryos of the nurse shark, but owing to insufficient material, not a great amount of work was accomplished. It is hoped that these experiments will be continued at some future time.

*The Movement of the Egg Nucleus in Relation to the Sperm Aster in Lytechinus variegatus,* by Edward L. Chambers

Eggs were transferred to a hanging drop according to the method of R. Chambers. Observations were made only when the egg was spherical and when the egg nucleus and sperm aster were at the periphery and in the same focus. When the egg is irregular in shape, the movement of the pronuclei is irregular. The observations consisted in taking the positions of the egg nucleus and sperm aster at intervals of 30 seconds with the aid of a camera

lucida. By plotting the points obtained the direction of movement and the rate of movement were obtained.

#### THE PATH OF THE SPERM ASTER

*The direction of movement*—In all the observations made, as soon as the sperm aster begins to develop it moves in a straight line to the center of the egg.

*The rate of movement*—The sperm aster moves with uniform speed from the periphery to the center.

#### THE PATH OF THE EGG NUCLEUS

*The direction of movement*—(a) When the angle subtended at the egg center by the sperm aster and the egg nucleus, the two latter being peripheral, is: (1) *ca.*  $0^\circ$  or  $180^\circ$ , the egg nucleus moves in a straight line toward the sperm aster; (2) *ca.*  $135^\circ$  or  $225^\circ$ , the nucleus moves along a curve described as being part of the circumference of a circle whose diameter is several times the diameter of the egg; (3) *ca.*  $45^\circ$  or  $315^\circ$ , the nucleus moves along a curve described as being part of a circle whose diameter is the diameter of the egg; (4) *ca.*  $90^\circ$  or  $270^\circ$ , the nucleus moves along a curve described as being part of the circumference of a circle whose diameter is one-half the diameter of the egg.

(b) If a tangent is drawn from a point on a curve describing the path of the egg nucleus, and projected until it intersects with the path of the sperm aster, the point of intersection will describe the position of the sperm aster corresponding to the position of the egg nucleus.

(c) (1) The time after insemination when the egg nucleus starts to move toward the sperm aster,  $v$ , is directly proportional to the distance of the egg nucleus from the sperm aster at the start,  $w$ , and inversely proportional to the distance of the aster from the center of the egg at the start,  $x$ . (2) The distance of the egg nucleus from the center of the egg at the position where it has just made contact with the astral center,  $y$ , is inversely proportional to the distance of the sperm aster from the egg nucleus at the time when the egg nucleus begins to move toward the sperm aster,  $w$ . (3) The size of the aster,  $z$ , is inversely proportional to its distance from the center,  $x$ .

Note that:  $v \propto w \propto 1/x \propto 1/y \propto z$ .

*The rate of movement*—If the rate of motion of the egg nucleus is plotted as ordinate against time as abscissa, a curve is obtained which rises gradually from the origin, levels out, and falls rapidly to the  $x$  axis.

That the movement of the egg nucleus is caused by streaming of the cytoplasm is evident from the observation that the granules immediately surrounding the egg nucleus move with it.

The positive acceleration suggests the existence of centripetal currents flowing toward the center of the sperm aster and becoming more and more intense as the astral center is approached. The diminished acceleration of the egg nucleus as it approaches the astral center suggests the existence of a resistance to the movement of the egg nucleus. The presence of a resisting material is further demonstrated by the deformation (ellipsoidal) of the egg nucleus during its approach to the astral center.

*The Coalescence of Sea Urchin Eggs with Oil Drops, by Robert Chambers and M. J. Kopac*

Spontaneous coalescence between oil drops and an unfertilized *Arbacia* egg denuded of its extraneous coats will occur if the tension of the oil in contact with sea water is above 9.5 dynes per cm.<sup>1</sup> The ova of *Lytechinus variegatus* and *Echinometra lucunter* were investigated for the purpose of determining if similar coalescence occurred and under what conditions. The investigations were also extended to fertilized and cleaving eggs and to blastomeres.

Following insemination and subsequent elevation of the fertilization membrane, the extraneous coats were removed, (1) from *Lytechinus* by drawing the eggs through a fine-bore capillary pipette and (2) from *Echinometra* by vigorous shaking for one minute. In order to inhibit or retard the formation of a hyaline plasma layer, the eggs during cleavage were immersed in a solution consisting of 4 parts 0.53 M. KCl and 1 part 0.52 M. NaCl. The duration of immersion in this solution was varied, ranging from 20 to 50 minutes depending on the nature of the experiment. The eggs were then returned to normal sea water.

The oils used were: (A) oleic acid (linolic acid-free), (B) white paraffin oil, and (C) oleic acid (1 per cent) in Squibb's Liquid Petrolatum. The approximate tensions of these oils in contact with sea water were 10, 30, and 3 dynes per cm. respectively.

In fertilized eggs of *Lytechinus* and *Echinometra*, spontaneous coalescence occurred at the instant of contact with oil drops from sample B. With A, coalescence occurred in all cases, but the drops were slightly larger than with B. In *Lytechinus*, coalescence with C occurred whenever the hyaline plasma layer was sufficiently removed. The diameters of penetrating oil drops from this sample were approximately 4 times larger than from A. Coalescence in *Echinometra* ova with C occurred only in exovates.

The tendency to coalescence in the furrow and polar zones of cleaving eggs (late amphister and later) was investigated and no difference was found. Oil drops were applied to the furrow or polar zone and the diameters of the drops at the instant of coalescence were measured. The diameters of the penetrating oil drops were the same at either position and independent of the nature of the oil, thereby indicating no difference in tendency to coalescence of these zones. This is of particular interest because the furrow zone has a much higher consistency than the polar zone. These results indicate that the physical state of the cell surface is a more important factor than the consistency of the cytoplasm in inhibiting coalescence—an idea previously advanced by the writers (*loc. cit.*).

The cleaving eggs of *Echinometra* were kept in the K-Na solution for varying lengths of time and then returned to sea water. Whenever these eggs were returned to sea water, coalescence with C was either retarded or inhibited. In many cases, particularly in those eggs kept in the K-Na solution for a short time, the hyaline plasma layer was distinctly visible. In these eggs coalescence with C was inhibited. This layer is firm enough to prevent the oil drop from making contact with the egg's surface. In all probability, the hyaline

<sup>1</sup> Robert Chambers and M. J. Kopac, *Jour. Cell. and Comp. Physiol.*, vol. 9, 331 (1937); M. J. Kopac and Robert Chambers, *ibid.*, vol. 9, 345 (1937).



plasma layer need not be visibly thick to prevent or retard coalescence. Completely denuded eggs, particularly those kept in the K-Na solution through cleavage, behaved like liquid spheres. Coalescence with C was instantaneous, resembling previous results obtained from aged, unfertilized eggs of *Arbacia*.

An interesting phenomenon was observed when cleaving *Lytechinus* eggs and oil B were used. Oil drops were applied to the furrow zone. The oil drop in this instance was completely incorporated. As the egg continued to divide, the oil drop became constricted to form in many cases two spheres joined by a short, thin stalk. This constriction was due to the closing in of the furrow concomitant with complete cleavage. This is a clear example of a cell's being capable of doing external work.

The work done by the egg is:

$W = \pi T [(d_2^2 + d_3^2) - d_1^2]$ , where  $d_1$  = diameter of original sphere in cm.,  $d_2$  and  $d_3$  = diameters of spheres resulting from constriction in cm.,  $T$  = tension of oil in contact with cytoplasm in dynes per cm., and  $W$  = work in ergs. The value of  $T$  is taken at 0.6 dyne per cm. The accompanying table shows the values calculated from some of our measurements. More accurate data are dependent on precise measurements of the tension at the surface of an oil drop in contact with cytoplasm. These determinations are now being made.

Work done by cleavage furrow

Diameters of oil drops			Work in ergs
$d_1$	$d_2$	$d_3$	
50 $\mu$	25 $\mu$	48 $\mu$	$8.0 \times 10^{-6}$
37	33	26	$7.4 \times 10^{-6}$
54	50	33	$12.5 \times 10^{-6}$
64	62	27	$8.9 \times 10^{-6}$
53	47	36	$12.9 \times 10^{-6}$

#### *Observations on the Swarming of the Atlantic Palolo, by Leonard B. Clark*

Various lines of investigation on the swarming of the Atlantic palolo were explored during the summer of 1937.

Systematic daily towings and observations showed that: (a) No large swarm occurred over West Loggerhead Reef during the summer although small numbers of eggs were found on July 13, 14, 15, 16, 17, 18, 27, and August 1. (b) Over Bird Key Reef eggs were secured on July 12, 13, 14, and 15 with eggs appearing in large numbers on July 14. Reproduction was complete by July 15, as no worms with mature sexual ends were found on search on July 15, 21, and 26.

Added illumination and shading of rocks containing sexually mature worms in live cars will induce or inhibit swarming, depending upon the intensity and time of illumination.

In the dark room, swimming sexual ends are positive to intensities from 0.0005 foot-candles (the threshold) to at least 50 foot-candles, and negative to gravity. Mature worms without sexual ends and immature worms are



positive to light from 0.001 to 0.01 foot-candles and negative to higher illumination. Differences were obtained in the behavior of mature and immature worms and between worms with attached and severed posterior ends.

Arrangements were made for the collection of worms during the winter 1937-1938 for a study of the development of the sex organs.

Rocks inoculated with palolo larvæ and controls were planted on Bird Key and Loggerhead reefs to study age of maturity as well as possible differences in development as related to differences in swarming.

### *The Stinging Mechanism of Sting Rays, by Paul R. Cutright*

The period from July 15 to August 10 was spent at Tortugas collecting material for studies on the sting mechanism of the sting rays.

The objects in view were : (1) a histological study of the mechanism itself; (2) a comparison of the mechanism in different species; and (3) a study of its development in one or more species.

At least three different species have been collected rather frequently at the Tortugas, and it was thought there would be no difficulty in securing at least two of them. During the week of July 15-23 three specimens of the southern sting ray (*Dasyatis hastata*) were caught, and within one of these were two embryos, each of a different age. From then on until the closing of the Laboratory only one more ray was seen. It would appear that the sting rays, following the habit of other elasmobranchs, make periodical or seasonal migrations close to shore and then, after a time, retreat to deeper water.

Enough material was secured, however, for a histological study of the mechanism as it exists in the southern sting ray and for a partial study, at least, of its development.

### *Studies on Crustacean Development, by Hugh H. Darby*

During a routine collection on June 13, a symmetrical specimen of *Cran- gon armillatus* was taken, having two snap-claws. This animal closely resembled the specimen figured by Coutière in 1899. Its importance lies in the fact that the two snap-claws produced in nature were indistinguishable from those induced experimentally by the writer during the past four years.

In an attempt to prevent the differentiation of the snap-claw, whole animals were subjected to gamma irradiation from radium. In this experiment the snap-claw alone was removed, the pinch-claw on the opposite side being left untouched. In the normal course of events, the remaining claw would appear as a snap-claw at the next molt. It was found that irradiation prevented differentiation only if applied immediately following the removal of the snap-claw. This showed that the differentiation of a mature pinch-claw into a snap-claw begins immediately on the removal of the snap-claw.

In previous work it has been shown that there is a competition for growth materials between growing claws on opposite sides of the animal. There is a similar competition between the dactylus and propodus of a single claw. The investigation of the latter, begun in 1936, was extended during the past

summer, in order to permit mathematical treatment of the measurements obtained. These experiments, together with the writer's older ones, show the importance of the distribution of certain specific chemicals which are furnished to the growing tissues only in extremely small amounts. This concept of the rôle of specific chemical substances harmonizes completely with current ideas on the organizer or on sex hormones. In the development of *Crangon*, the superior ability of certain tissues to withdraw these materials from circulation appears to be of prime importance.

*Mangrove Vegetation and Land Building, by John H. Davis Jr.*

The object of the writer's twelve-day stay was to determine the advantages of the Tortugas atoll for use as one of the experimental stations in his investigation of the rôle of mangroves in building land. A botanical reconnaissance was made of the islands and three species of mangrove with two varieties of buttonwood were found. *Laguncularia*, growing abundantly around a pool on Long Key, was over ten years old but had not been formerly reported here. The vigorous growth of these mangrove plants indicates that the calcareous sands of these islands will support mangroves.

On Bush Key Reef young *Rhizophora* and *Avicennia* plants have begun the formation of a primary mangrove island. Over 200 *Rhizophora* seeds were planted here to determine survival and rate of growth on the coral fragments with little calcareous sand. If these adequately survive, and the naturally established plants show increase and continued growth, large plantings will be made in 1938 in an attempt to build up the reef with mangrove growth. Other experimental plantings were made about the pools and on the upper beach of Long Key.

Good results were obtained from observations on the *Rhizophora* seeds washed ashore on these islands. The abundance, age, and location of these seeds in respect to the prevailing winds gave information as to their mode and rate of dispersal. Since there are no mature *Rhizophora* plants near the sea water on these islands, the seeds collected must have come from the Marquesas or other mangrove areas to the east of this atoll. A thorough check on the dispersal of *Rhizophora* seeds is planned for 1938.

A preliminary study of the strand vegetation of these islands was begun and even with these few observations many changes were observed that have occurred since former botanical reports. Certain vegetational changes are taking place here that should be periodically observed and recorded.

*The Rôle of Fin Movements in the Equilibrium of the Fish, by John E. Harris*

1. The anatomical structure of the brachial plexus in the red grouper, *Epinephelus morio*, has been found to agree in all essential features with that of the silverside, *Menidia*, described by Herrick. Three segmental nerves—occipital nerves *b* and *c*, and spinal nerve 2—are concerned in the movement of the pectoral fin.

Experiments referred to in the Tortugas report for 1935 (Year Book No. 34) showed that the muscles to the fin rays of the pectoral fin were supplied in regular order by segmental nerves. These experiments, originally per-

formed on isolated fin preparations, have now been repeated and the results confirmed by sectioning the brachial nerves in the living fish. There appears to be a significant overlapping in the motor nerve supply to adjacent segments of the fin. If one of the three brachial nerves is sectioned, movement of all the pectoral fin rays is still possible, though the muscles of that part of the fin corresponding to the cut nerve are less powerfully contracted than normally. If, however, the two adjacent occipital nerves, *b* and *c*, are both sectioned, the muscles to the upper (anterior) part of the fin are no longer active. Under such circumstances, for example, there can be no erection of the fin, since this requires the action of the arrector musculature attached to the first fin ray.

Most of the operated fish survived with no apparent injury, and material was obtained for a study of the degeneration of the medullated fibers after the transection.

2. The morphology and function of the deep tail musculature was studied in a number of fish species. The present system of nomenclature implies for some of these muscles an erroneous idea of their action on the caudal fin. Electrical stimulation experiments have clearly established the function of these deep muscles, and a small comparative study has been made which shows a very clear correlation between the size of the different caudal muscles and the action of the caudal fin in various types of fish.

3. Work has been continued on a general study of the locomotion of the Plectognathi. It has been found possible to relate the evolution of the different families in this group not only with morphological, but also with functional changes in the fin mechanism used for producing and controlling locomotion.

4. Measurements have been made of the dimensions of a number of species of acanthopterygian fishes, the position of the center of gravity, the size, shape, and position of center of pressure of the fins, and other relevant data being determined. It is hoped that a statistical analysis of the data will yield information concerning the interaction of the fin systems. There is, for example, a significant positive correlation between forward migration of the pelvic fins and upward motion of the pectorals. The close relationship which has been found to exist between the longitudinal position of the center of pressure of the spiny dorsal fin and the center of gravity of the fish body is probably related to the use of this fin as a balancing keel, and as a mechanism for producing directional instability during turning movements. The shapes of many of the fins, though impossible to express as scalar quantities, are also significantly related to their function.

5. Studies have been made of the bony structure of the pectoral girdle and its relationship to the musculature of the fin in a number of fish species. Increase in size of the primary shoulder girdle, and particularly of its coracoid element, is always associated with pectoral fin locomotion, being found in the Labridæ, Chætodontidæ, Plectognathi, etc. The scapular element is of importance in taking the thrust of the muscles inserted on the leading (upper) edge of the fin, and this element therefore becomes stronger in those forms (Carangidæ, Scombridæ, etc.) using the pectoral fins largely as brakes. In forms employing the pectoral fins for forward locomotion, the axis of the



glenoid articulation is more nearly horizontal, and the glenoid surface and musculature to the first fin ray are much smaller than in forms using these fins for braking or backing movements.

6. In order to determine accurately the differences in pectoral fin motion of some of these fishes, a number of cinematographic studies have been made of fin movement in the Labridæ (*Lachnolaimus*), Chætodontidæ (*Pomacanthus*), and Serranidæ (*Epinephelus*). Records have also been obtained of the fin movement after transection of the brachial nerves in *Epinephelus*.

Diving observations have further extended a knowledge of the swimming habits of various species in their normal habitat.

#### *Regeneration in the Genus Holothuria, by Frank R. Kille*

Of the material obtained last year, the series on *Holothuria floridana* proved to be the most favorable for the histological analysis of the origin of the regenerated digestive system in this genus. The early stages of regeneration (4 to 8 days after evisceration) proved to be especially significant, but the number of specimens was inadequate. By using the procedure developed last summer sufficient material was obtained this year to complete the study of this species.

Particular attention was given to *H. parvula*. This species was found in large numbers among the coral on the shallow flats northwest of Bird Key Reef. It also occurs on the higher levels of the reef but is less abundant. Because of its small size this form is a convenient holothurian for the laboratory and for histological examination. When kept for a week in running-water aquaria in our laboratory many autotomized the intestine through breaks in the body wall. Most of these died and others were in poor condition. All methods reported to date for inducing evisceration in either *Thyone* or *Holothuria* resulted in the death of *H. parvula*. It was found, however, that the following simple procedure would give good results. Pressure was applied by the fingers to the dorsal body wall. One prong of a sharp-toothed forceps was then inserted through the anus so that a small tear could be made in the cloaca. In most cases the tear also involved a small portion of the adjacent body wall. The gush of cœlomic fluid was immediately followed by a portion of the intestine if the pressure was continued. A gentle pull on the intestine would remove it from the body along with the rete mirabile and the left respiratory tree. Of 188 specimens so treated, 99 lived until killed for examination after various periods of regeneration ranging from 2 to 33 days. A series of stages was thus obtained for *H. parvula* which approximates the complete series now on hand for *H. floridana*. The rudiments of the new digestive systems within 34 specimens were drawn with the aid of a dissecting microscope ( $\times 29$ ) and a camera lucida. The tissues were then removed and stored for later histological analysis. So far as one can determine macroscopically, regeneration in *H. parvula* resembles that reported for *H. floridana* in all essentials.

Since *H. parvula* undergoes transverse fission in nature, it provides excellent material for the problem of the regeneration of the gonad as well as the lantern, esophagus, cloaca, and their associated structures, which are never



autotomized in this genus. For comparative purposes *H. parvula* will serve as a valuable transitional form between the Holothuria and the genus *Thyone*, which will autotomize the extreme anterior tip of the body and the entire alimentary canal with the exception of the cloaca. Examination in the field of 1150 *H. parvula* during June and July showed that at least 109 were regenerating a new extremity. A portion of these were killed and fixed for microscopic examination, thus adding to the material obtained at the close of last summer's stay.

In order to obtain the earliest stages in regeneration, and also to time those specimens collected in nature, groups of eviscerated and uneviscerated *H. parvula* were transected in the laboratory and returned to coral-filled cages on the sea bottom. Of the 50 specimens composing the uneviscerated group, 41 anterior halves and 39 posterior halves lived until killed for examination, while of the 98 specimens in the eviscerated group only 59 anterior halves and 45 posterior halves survived.

To test the potency of the mesentery when entirely free from any remnants of the original alimentary canal, the middle third of the body was isolated from 54 specimens. Only 2 such sections were alive 11 days after the operation. These showed opaque thickenings of the mesentery edge which appeared to be without a lumen, a condition which characterizes this level of the mesentery within whole animals in the first stages of regeneration. The survival of the anterior and posterior thirds of animals composing this group was 28 and 18 respectively.

*The Coalescence of a Plant Cell with Oil Drops, by M. J. Kopac*

Since many animal cells, particularly sea urchin eggs, coalesce with oil drops, it is reasonable to suppose that similar phenomena may occur in plant cells. The cells must, however, be denuded of all extraneous coats. The most important extraneous coat on the plant cell is the cellulose wall. This can be removed from some plant cells by micrurgical technique. Fortunately, this step was unnecessary in the case of young aplanospores of *Valonia ventricosa*.

The aplanospores for these experiments were easily obtained. The puncturing of large coenocytes with a glass capillary initiates a series of reactions which result in the production of minute spheroidal bodies, the aplanospores. At various times, ranging from 30 minutes to several hours, the aplanospores were transferred from the coenocyst to hanging drops on cover slips. The oil drops were then applied to these cells. In this series of experiments, a Chambers micromanipulator was equipped with two micropipettes. This arrangement permitted the application of two different oils on the same aplanospore with only a few seconds' interval between the two applications.

The oils used were: (A) oleic acid (linolic acid-free), (B) white paraffin oil, and (C) oleic acid (1 per cent) in Squibb's Liquid Petrolatum. The approximate tensions of the oils in contact with sea water were 10, 30, and 3 dynes per cm. respectively.

Very young aplanospores readily coalesce with oil drops since they are naked protoplasts. Older aplanospores coalesce less readily. This decreas-

ing tendency to coalesce with oil drops is believed to signify the building up of extraneous coats by the protoplast. For example, aplanospores ranging in size from 19 to 93  $\mu$  coalesced with C up to 1.5 hours. After that the probability of coalescence with this oil was very small. However, aplanospores at this time would coalesce with oil A. After 2.5 hours coalescence with A was highly improbable. After 3.5 hours the aplanospores would not coalesce even with B. A membrane surrounding the aplanospore is visibly evident in these older cells.

Another observation emphasizes the gradual appearance of an organized surface on the aplanospore. In the early aplanospores, coalescence with an oil drop almost invariably causes a destruction of its original contours. Frequently the protoplast breaks down leaving an oil drop completely coated with an irregular mass of chloroplasts and cytoplasmic residue. In the older aplanospores this tendency is lost, and the original contours persist following coalescence.

Upon Dr. F. C. Steward's suggestion, the Zander's zinc chloride-iodine test was applied to the older aplanospores to determine if the visible membrane was composed of cellulose. The tests performed at Tortugas were highly suggestive, but the chloroplasts still contained too much pigment to permit one to decide conclusively whether the incipient wall was blue. The chlorophyll in these cells was extracted by alcohol. Evidently the chloroplasts contain some other pigment which is not appreciably soluble in alcohol. These tests are being continued at Woods Hole on *Valonia* shipped thither from Tortugas. Other extracting media will be tried so that all pigment will be removed from the chloroplasts.

Among the many interesting observations were the following: The frequency of coalescence with C was low in aplanospores 1.5 hours or more old, particularly if the oil drops were small. A drop of C was first applied to an aplanospore. In case no coalescence occurred, a drop of A was applied to the opposite side of the aplanospore. This drop immediately snapped into the cell. From 0.5 second to several minutes later, oil drop C would snap into this aplanospore. This reaction, repeated at will, shows that the surface of the aplanospore may become broken down so that coalescence with oils of low tensions will occur. Since these cells are still capable of coalescing either with A or with B, it is highly improbable that an appreciable cell wall has formed. This protoplast may be considered as a naked cell, and the inhibition of coalescence with C may be due to a preliminary solidification at the cell surface prior to the laying down of cellulose. If this is true, the subsequent coalescence of a cell with C following coalescence with A may be explained on the basis of a peripheral disorganization at the cell surface. Similar phenomena have been observed in immature sea urchin eggs (Robert Chambers, unpublished data.) Over-insemination of these eggs produces large insemination cones which tend to flow together. When one spot is injured with a microneedle the entire surface film suddenly disintegrates. Thus in the aplanospores, the coalescence of A apparently induces a disintegrative effect on the cell surface (similar to the action of a microneedle on *Arbacia* eggs) which then permits coalescence with C.

*Some Observations on the Coral Reef Area of Tortugas, by M. Lecompte*

The palæontologist studying fossil corals and reefs meets great difficulties. The complex conditions which govern the development of these fixed organisms escape his investigation. The difficulty of systematic observations in the fossil exposures may lead to a misinterpretation of the species among organisms so intimately related to their environment. The significance of the structures of their skeletons in the determination of the species is also a thorny question. When, exceeding the limits of mere description, the palæontologist tries to interpret the geological calcareous formations constructed in greater or less part by the corals with the aid of other organisms, he meets much greater obstacles. Direct observation of living corals and reefs soon appears to be necessary to the efficient pursuit of his researches.

A period of study at the Marine Biological Laboratory at Tortugas, made possible through the kindness of the Carnegie Institution of Washington, fulfilled one of the writer's strongest wishes. His purpose was not to pursue any particular research but to form a general acquaintance with the various conditions which govern the growth of a coral reef.

During the short time spent at the Tortugas Laboratory a large quantity of corals and bottom samples were collected in the diverse parts of the Tortugas area. The writer intends to study this rich material in Brussels from the point of view which particularly interests him, and later to publish the results if they appear interesting. Until microscopic studies have been made it will be impossible to make a detailed statement regarding this study.

Particular attention has been paid to the distribution and the adaptation of the corals on the reef. The observations made by the writer have for the most part been carried out before and do not need to be repeated here. It is nevertheless well to point out the remarkable distribution which appears west of Loggerhead Key. From the shore and parallel to it, after a grassy area, one meets successively the following zones:

- (a) Massive forms among which *Orbicella annularis*, in big heads with frequent necrosis on the top, prevails. Gorgonians commonly cohabit with these forms, but in this area the plants occupy separate patches. So far as the writer has been able to observe, they are excluded wherever vigorous growth of corals takes place.
- (b) Bunches of *Acropora cervicornis* moderately or poorly developed with a few massive forms still present.
- (c) A large area of about 400 yards with corals rare or absent. This zone, which spreads over depths of approximately 18 to 20 or 25 feet, is characterized by gorgonians and algæ. Shoreward the gorgonians are well developed but they become progressively smaller toward the outer limits of the zone.
- (d) A large area of the same breadth, at the depths of about 22 to 35 feet, with big patches of vigorous *Acropora cervicornis* well developed in height. The upper branches are more widely ramified than the lower ones.

The writer has verified this regular distribution on a base line of about 2500 yards. The existence of a large and regular sterile zone in the area of *Acropora* should perhaps merit some particular research.

As concerns the adaptation of the forms to the environment, some beautiful examples were observed, notably in the case of *Acropora cervicornis*. In



typical areas of massive forms this coral enlarges itself considerably in deformed body or inflated, irregular, and anastomosed branches. Only their upper parts differentiate in branches of the usual size, but even these are stumpy. So far as the writer has been able to study this phenomenon, which needs more observations than could be made in such a short time, it appears that the branchiate forms are more susceptible than the massive ones to adaptation to diverse environments. On the whole it seems that corals are strongly adapted to particular conditions and do not endure change very successfully. The massive forms are restricted to the area of relatively clear water included between the area where the precipitation of  $\text{CaCO}_3$  occurs and the region where sand is deposited. In the actual conditions of the Tortugas area, these limits strongly restrict the dispersal of the massive forms.

One of the most interesting observations is the fact that the corals feed principally, if not exclusively, during the night, as Wood Jones and J. E. Duerden have pointed out for other reefs, contrasting with their companions, the gorgonians, which are seen fully expanded during the day. Further knowledge of the rôle of the zoöxanthellæ is desirable. It is not certain that the association of algæ with reef corals has existed throughout the duration of geological time. If light has not always been essential to the development of reef corals, the deductions on the depth conditions of their growth in geological time need careful examination.

The destructive action of organisms on the massive living corals seems weak, if it takes place at all. So far as the writer has observed, the *Milleporæ* grow only on the dead part of the massive corals. The same coral does not reestablish itself on its dead parts. The tube worms do not ravage the colony. It should nevertheless be interesting to see if they have no effect on the development of the colony and the reason for their preference for some particular kinds of corals. The big heads of *Orbicella annularis* are only rarely inhabited by tube worms, contrasting with the *Mæandra* and *Porites astreoides*, in which they are usually abundant.

On the dead corals, the action of boring animals is very intense, as is well known. The more the rock is altered, the more numerous are the boring animals. It was not determined whether alteration of the rock is caused by secretions of these organisms or whether inorganic dissolution begins earlier. The remains of the branchiate corals are less attacked by the boring animals.

Some interesting phenomena of dissolution can be observed on the beach rock of Loggerhead Key. This rock of very recent consolidation, as indicated by the bricks, bottles, and other objects enclosed, is filled with little excavations. These excavations are all elongated toward the sea. Thus the mechanical action of the waves and the sand appears clearly. In a great number of these holes one finds a much eroded coral or a shell. On the other hand, the holes diminish in number and in dimension from the external limit of the bank toward the sea. Thus it seems that the excavation of the rock is initiated by dissolution of more soluble parts and is completed by mechanical action.



*Tumors Probably of Nervous Origin in Fish of the Snapper Family (Lutianidæ), by Balduin Lucké*

While a considerable variety of tumors have been observed in many different species of marine fish, hitherto no kind of tumor has been found with sufficient frequency to make it readily available for study. The abundance of fish in the waters about the Tortugas and the exceptionally favorable collecting facilities of the Laboratory afforded the opportunity for discovering that certain kinds of tumor commonly occur in several species of snappers (Lutianidæ). These tumors arise in the corium or subcutaneous tissue, whence they project outward as flattened oval masses, stretching the covering epiderm to a delicate membrane devoid of scales. They vary in size from small nodules to conspicuous masses over 4 cm. in diameter. No particular part of the surface appears to be most commonly affected, tumors having been observed on the head, body, and tail, and on the dorsal as well as on the ventral surface. Usually but one growth is present, though two, three, or even four tumors may occur. They are firm and resilient in consistency, and have a white, usually moist, cut surface, which is nearly homogeneous in some, striated or whorled in others. At their base some are sharply delimited, others infiltrate the subjacent tissue. However, despite the rather uniform naked-eye appearance of the tumors, there is considerable variation in their structure. They are composed of cells resembling fibroblasts, of fibrillar tissue, and homogeneous intercellular substance, the proportion of these components varying greatly. Some are richly cellular, others are fibrous or even partly hyaline; whether cellular or fibrillar, they usually have a distinctly fasciculated makeup, the cells being arranged in interlacing bands and whorls. In many tumors the oval nuclei are grouped in a peculiar manner forming more or less parallel rows or palisades, between which lie dense masses of fibrils or nearly homogeneous tissue. In places there are structures resembling nerve fibers. Areas of degeneration, hyaline or mucinoid, are common in the larger growths. The more cellular tumors somewhat infiltrate the adjacent tissue; the more fibrillar growths are sharply circumscribed though usually not encapsulated. No metastasis has been observed.

Neoplasms of this kind were found in 39 fish belonging to three species of snappers, the gray snapper (*Lutianus griseus*), dog snapper (*L. jocu*), and schoolmaster (*L. apodus*). All the specimens were mature and of average or large size. Though many fish of other families were examined, no tumors of this kind were observed. Transmission experiments were not successful, the inoculated fish dying within a few days, whether from operative procedures or from other causes is not certain. It is possible that a different technic may get better results.

The tumors here reported closely resemble the complex group of human neoplasms arising from nerves. Like them they show the palisade arrangement of nuclei characteristic of the neurogenic group. An additional point of resemblance to neurogenic tumors is the occurrence of structures resembling nerve fibers.

The relative ease with which these tumors may be secured in the Tortugas (and possibly elsewhere in tropical waters) renders them very favorable material for the study of an important group of neoplasms.

*The Rôle of CO<sub>2</sub> in the Effect of Light on the E.M.F. of Valonia ventricosa,*  
by Gordon Marsh

The study of the effect of light on the E.M.F. of impaled *Valonia* (Year Book No. 35, pp. 88–89) was continued, with emphasis upon the influence of the partial pressure of carbon dioxide. CO<sub>2</sub> and O<sub>2</sub> or N<sub>2</sub> from commercial tanks were mixed in definite proportions and passed continuously through the sea water bathing the cells. Dissolved CO<sub>2</sub> was removed by aeration with CO<sub>2</sub>-free gas.

The normal dark potential of *Valonia* (inside positive by about 10 mv. at 30° C.) is reduced along a roughly exponential curve as the concentration of CO<sub>2</sub> in the external medium increases. The electrical polarity is reversed at approximately 5 per cent CO<sub>2</sub>, and the curve has practically reached an asymptote at 40 per cent CO<sub>2</sub> with the inside negative by 5–12 mv. Concentrations up to 40 per cent produce no injury, but pure CO<sub>2</sub> applied for two or more hours causes irreversible coagulation of the protoplast. The effect of CO<sub>2</sub> upon the dark potential is in part, at least, due to change in pH of the sea water, as will be shown in a subsequent paper.

The normal polarity may be restored by light, the intensity necessary being greater, the higher the percentage of CO<sub>2</sub> to which the medium is equilibrated. The curves of E.M.F. versus light intensity for concentrations of CO<sub>2</sub> of 10 per cent or less are similar to those previously obtained in unstirred sea water, save that *no maximum appears* and the total change in E.M.F. increases with the concentration of CO<sub>2</sub>. (Because of the great penetrability of CO<sub>2</sub> and the extremely small amounts used in photosynthesis, even intense light can cause but a negligible change in internal pH). The threshold intensity of light (the smallest intensity at which a clearly visible change in E.M.F. occurs) is less for cells equilibrated to low concentrations of CO<sub>2</sub> than for cells in either unstirred or CO<sub>2</sub>-free sea water. It was not possible to abolish the light effect by removal of dissolved CO<sub>2</sub> from the medium, presumably because of the rich supply of bicarbonate. The decline in potential of cells in unstirred sea water during prolonged exposure to intense light reported previously could be arrested by aeration with CO<sub>2</sub>. In some experiments it was possible to increase or decrease the potential at will by addition or removal of CO<sub>2</sub>.

The magnitude of the dark potential was found to be determined by the nutritional state of the cell with respect to stored carbohydrate. In complete darkness the dark potential undergoes a continuous decline which is greater during the first few days. In one instance the E.M.F. fell from 10 mv. to 0.2 mv. over a period of twenty-nine days, with subsequent recovery. Exposure to light, especially in the presence of an abundance of dissolved CO<sub>2</sub>, had the opposite effect, the dark potential reaching or even exceeding its normal value in a few hours. With intensities of several thousand foot-candles the dark potential could be raised to as much as 20–30 mv., from

which level several days were required for return to normal values. Cells kept in the dark became translucent and even transparent owing to loss of starch; exposure to light restored the normal opacity or increased it. In both cases the E.M.F. was affected before the changes became visible to the eye. In all the experiments there was abundant evidence that the absolute magnitude of the E.M.F. is determined by the previous history of the cell as well as by its immediate environment.

A limited number of experiments were performed to test the effect of temperature on the E.M.F. in light (in unstirred sea water), supplementing previous work at light intensities below 100 foot-candles where a large  $Q_{10}$  is found. Between 200 and 1200 foot-candles, where the E.M.F. is two to five times the dark potential, the temperature coefficient is of the order of 1. At intensities of the order of 10,000 foot-candles the  $Q_{10}$ 's are of the same magnitude as for weak light.

These results reenforce the earlier conclusions that light affects the inherent E.M.F. of *Valonia* through the photosynthetic mechanism; that the potential is conditioned, but not caused, by the electrolyte composition of the sap and of the medium; and that the source of the potential is an oxidation-reduction system maintained in *flux equilibrium* at any constant state of the environment by the combined influences of the cell metabolism.

*Investigations on Ascidians, by Harold H. Plough and Norris Jones*

Since collecting during the 1936 season brought to light several undescribed species of ascidians, Mr. Jones has become associated in the work of collecting, studying, and illustrating the material. It is hoped to publish one or more monographs covering the more important ascidian genera of the Tortugas, certain of which have nowhere been adequately figured. During the current season we have attempted to cover the genus *Ecteinascidia* Herdman, including the description of a new species which we have called *Ecteinascidia tortugensis* (first found at Tortugas by Professor Caswell Grave).

The list of ascidians of the Tortugas Islands now totals 37 species. Although this cannot be considered complete, it certainly includes all of the more common species, and it seems desirable to put it on record. It extends and corrects the list of genera given by Hartmeyer in the Year Book for 1908.

ASCIDIACEA OF THE TORTUGAS

Aplousobranchiata

Synoicidæ

*Polyclinum constellatum*

*Amaroucium pellucidum*

*Amaroucium* sp. nov.

*Aplidium lobatum*

Didemnidæ

*Trididemnum savignii*

*Didemnum candidum*

*Diplosoma macdonaldi*

*Echinoclinum verrilli*

*Lissoclinum fragile*

Polycitoridæ

*Polycitor olivaceus*

*Polycitor convexus*

*Polycitor hepaticus*

*Clavelina picta*

*Distaplia bermudensis*

Phlebobranchiata

Asciidiidæ

*Perophora viridis*

*Perophora bermudensis*

*Ecteinascidia turbinata*

*Ecteinascidia conklini*



Ascidiiidæ— <i>Continued</i>	Styelidæ
<i>Ecteinascidia conklini</i> var. <i>minuta</i>	<i>Symplegma viride</i>
<i>Ecteinascidia tortugensis</i> sp. nov.	<i>Symplegma viride</i> var. <i>minuta</i>
<i>Ascidia nigra</i>	<i>Polycarpa obtecta</i>
<i>Ascidia curvata</i>	<i>Polycarpa spongiabilis</i>
<i>Ascidia hygomiana</i>	<i>Polyandrocarpa tinctoria</i>
	<i>Polyandrocarpa gravei</i>
Stolidobranchiata	<i>Polyandrocarpa maxima</i>
Botryllidæ	<i>Polyandrocarpa sabanilla</i>
<i>Botryllus planus</i>	<i>Styela partita</i>
<i>Botryllus schlosseri</i>	<i>Pyura vittata</i>
<i>Botrylloides nigrum</i>	<i>Microcosmus exasperatus</i>

In addition, the senior investigator continued the work, noted in the 1936 report (Year Book No. 35), of studying experimentally produced composite colonies of *Ecteinascidia* and *Perophora*. Growing points of stolons about 2 mm. in length were cut off in sea water, and pairs from different species were twisted about each other and crushed lightly. Trophocytes and mesenchyme cells were extruded at the cut and injured surfaces. In about half the cases these cell masses aggregated and the surfaces healed by overgrowth of ectoderm and a thin test, to form composite stolons. Such intergeneric stolon grafts grew out stolon branches and zooids were budded off. Certain strands consisted of tissues of either one species or the other as shown by the type of zooid, but the intermediate form of some zooids indicated that they were true chimæras. Successful composite colonies were secured only if stolon pieces of *Ecteinascidia tortugensis* were used, and combined with *E. conklini* or with *Perophora bermudensis*. Because of the short season none of the intermediate zooids were carried to sexual maturity. Since in these ascidians the zooid is derived from a mass of undifferentiated mesenchyme cells in the bud, these experimental chimæras offer interesting possibilities for the study of genetically different tissues in differentiation.

*Studies of the Ciliates of Sea Urchins, by Philip B. A. Powers*

One of the main objectives of these studies of ciliates infesting echinoids is to use this convenient association as a source of protozoa for a detailed investigation of ciliate anatomy for species as yet unknown to laboratory cultures. Just now these ciliates fall into four groups related respectively to the genera *Metopus*, *Cryptochilidium*, *Anophrys*, and *Cyclidium*. The members of each group present different mechanisms for feeding, body symmetry, and behavior, features of ciliate architecture about which there is still much to learn.

This summer's work dealt principally with an intensive analysis of the detailed morphology of the genus *Metopus*. In view of its abundance and general excellence *M. circumlabens*, which infests the gut lumen of *Centarchinus antillarum*, was arbitrarily selected as the basic type against which other members of this genus might be compared. Although considerable data have already been assembled from previous work, several obscure details remained to be clarified from a study of living material, details concerned primarily with the mechanism of ingestion and the classification of various cytoplasmic constituents.



1. *Ingestion.* While the general details of the fibrillar system of *Metopus* are known from studies of stained sections, it was very necessary to confirm some of these observations by following the behavior of various parts during feeding. By allowing various individuals to ingest particles of lampblack or carmine, it was possible to coordinate the action of the various mouth parts with the formation of food vacuoles. From ten to twenty minutes were required to fill a primary food vacuole. Through the selective action of the undulating membrane and a brush of fine cilia guarding the entrance to the primary food vacuole, nutrient particles, principally bacteria, were packed into the newly forming food vacuoles. From the point of its origin the food vacuole moves along a canal associated with the inner surface of the pharyngeal strand until it is forced into the endoplasm in the region of the terminal coil. This terminal coil appears to be an anchor for the distal end of the pharyngeal strand.

2. *Fluorescent endoplasmic components.* An investigation was made of the reaction of the cytoplasmic components of *Metopus* when treated with fluochrome dyes and examined for fluorescence using a high-intensity mercury vapor lamp (85-watt miniature quartz lamp operating on 440 volts). With this technique it was hoped that the terminal coil of the pharyngeal strand and its ramifications about the gullet could be differentiated in vivo. This end was not achieved, and the main branches of the fibrillar system could be only faintly discerned in the dead individual, an observation for which fluorescence microscopy has no advantages over the use of visible light. The use of ultraviolet equipment is well justified, however, in the investigation of the vacuoles, nuclei, fats, lipid particles, and other inclusions. When the natural fluorescence is intensified through the use of dilute solutions of fluochrome dyes, the various components are strikingly set apart, and while the use of fluorescence microscopy is as yet an unexplored field in respect to protozoology, it offers great promise because the simple technique involved leaves the specimen in a more nearly unaltered state than any other method of analysis now in use. The most satisfactory of the fluochrome dyes as to brilliancy of differentiation was a 1:250,000 dilution of acridian yellow (Grübler). In visible light this dye diffuses uniformly throughout the entire animal and is nonspecific except for certain excretion products, moreover its toxicity is so low as to allow the examination of animals for several hours in vivo. For specimens killed in 2 per cent formalin, the most satisfactory fluochrome dye was coriphosphin O (Pfaltz and Bauer) diluted 1:50,000. Other dyes which proved less satisfactory are listed in the order of their usefulness: berberin sulphate, geranin G, thioflavin S, thiazol yellow, and rosol red B extra. With an improved dark-field illuminator, possibly of the Smiles type, many of the present difficulties could be overcome. However, with the present equipment, identification of glycogen, neutral fats, and fatty acids, as well as other endoplasmic components, could be made.

#### DISTRIBUTION OF INFESTATION

The ciliates infesting West Indian echinoids are generally characteristic for all of the hosts associated with the Gulf Stream. While a few of these ciliates have been reported from sea urchins of the Yellow Sea, similar species

have never been recorded from the echinoids of our Pacific coast bathed by the California current. Last summer opportunity was afforded to examine the ciliates infesting three species of sea urchin (*Strongylocentrotus franciscanus*, *Helicidaris stenopora*, and *Toxopneustes roseus* as identified by Austin Clark), all taken from the waters about Acapulco, Mexico. Here the intestinal fauna is distinctly similar to if not identical with that found among the echinoids at Tortugas. The hosts, however, are the same species of sea urchin as are found about the coast of California, where entirely different ciliates compose the infestation.

In the specimens of Acapulco sea urchins collected from not over four fathoms, *Cryptochilidium bermudense* was the dominant form, while those taken from the shore line harbored *Metopus circumlabens* and a smaller form *Metopus* sp.?, *Cryptochilidium bermudense* and a *Cryptochilidium* sp.? similar to a form described from Japanese Echini, *Anophrys elongata*, *Cohni-lembus caeci*, and *Cyclidium* sp.?. Why these ciliates do not follow their hosts northward along the Pacific coast cannot be told. It is possible that not the host but rather the physical characteristics of the Southeast Moonsoon Drift, which washes the Acapulco area, controls the fauna within its influence, while the peculiarities of the California current limit the infestation of its sea urchins. Certain it is that the similarity between the infestation at Tortugas and Acapulco points to the same common origin for each of these now well-isolated groups—a common origin well established long before the present land masses of Central America had separated the Atlantic and Pacific oceans. The time which has elapsed during this period is well demonstrated through the general topographical changes as well as the establishment of echinoid species peculiar to each locality; evidence of both inorganic and organic evolution which has occurred in the habitat of ciliates although they themselves have for the most part remained unchanged. It will be of considerable interest to analyze carefully each of the component ciliates of the Acapulco group to determine if any appreciable modification in species has taken place when compared with the data assembled from the ciliates of the Tortugas echinoids. This is a most appealing problem, for it deals with some of the basic concepts of biology, namely, variation and the dispersal of species.

*Further Investigations on the Physiology of Valonia*, by F. C. Steward and J. A. Harrison

Salt accumulation by plants has been profitably investigated by the use of indicator ions which are readily accumulated but not present initially in the organism concerned. The bromide ion has been outstanding in this connection. Previous attempts<sup>1</sup> to utilize bromide as an indicator ion with *Valonia* were unsuccessful because this ion is not readily accumulated by these plants, a result which may be ascribed to the fact that accumulation of the bromide ion commonly occurs in systems capable of active growth

<sup>1</sup> F. C. Steward, Salt absorption and respiration of *Valonia*. Carnegie Inst. Wash. Year Book No. 32, 281-283 (1933).

F. C. Steward and J. C. Martin, The distribution and physiology of *Valonia* at the Dry Tortugas, with special reference to the problem of salt accumulation in plants. Carnegie Inst. Wash. Pub. No. 475, pt. VI, 87-170 (1937).

and metabolism, and these properties are lacking in the relatively large isolated vesicles of *Valonia ventricosa* and *V. macrophysa*. For the case of *Valonia*, therefore, the alkali metals other than sodium or potassium promised to be more effective indicators of absorption, especially so since one of them (rubidium) has been supposed to enter and accumulate rapidly in *V. ventricosa*.<sup>1</sup> The absorption of these ions might occur in two ways: either by the primary process of salt absorption, in which both anion and cation are simultaneously absorbed, or by interchange with potassium already present in the sap. The former process is characteristic of cells in rapid growth and the latter of cells relatively more mature and of less active metabolism.

The principal objective, therefore, of this investigation was to determine the relative rates of absorption of the elements Li, Rb, and Cs by the *Valonia* species available at Tortugas and the factors which determine their accumulation.

A spectrographic method was employed for the quantitative determination of the alkali metals in small volumes of *Valonia* sap or of sea water. Determinations have been carried out on volumes of sap as small as 0.025 cc. The method was based upon a procedure briefly described by Ramage<sup>2</sup> and has been perfected and modified by the authors, who have used it in a quantitative comparison of the uptake of rubidium and bromide by potato tissue (results awaiting publication). A Hilger wave-length spectrometer was used and all the necessary combustions were carried out at Tortugas under standard conditions, using an oxyacetylene flame. The conditions were so standardized that, using 0.05 cc. of sap, the concentration ranges suitable for quantitative work were as follows: lithium 0.027 to 0.0027 equivs. per liter, rubidium 0.0008 to 0.0001 equivs. per liter, caesium 0.004 to 0.0005 equivs. per liter. To overcome the comparative insensitivity of the method in the case of lithium, the volume of the aliquot part of the sap used for each determination was increased (volumes as great as 0.5 cc. have been used), and for the determination of rubidium the saps often required dilution. Approximate determinations were made by visual comparison of the unknowns with lines produced on the same plate by a series of known amounts of standard solutions. The exact quantitative determinations have yet to be made by the use of the microphotometer, and this work will be done at Birkbeck College, University of London. Total halide determinations were made on small volumes (e.g. 0.05 cc.) of sap by titration with silver nitrate in the presence of acetone and dichlorofluorescein as indicator.

Using these methods, very small vesicles of *V. ventricosa* could be used. Observations were also made for the first time upon the sap composition of *V. ocellata*.

The halide concentration observed in the sap of *V. ocellata* (mean of 10 samples = 0.704 equivs. per liter) is significantly greater than those which are characteristic of *V. ventricosa* and *V. macrophysa*.<sup>3</sup> The higher halide

<sup>1</sup> S. C. Brooks, The rate of penetration of rubidium into living cells of *Valonia* and its relation to apparent ionic radii. Jour. Cell. and Comp. Physiol., vol. 2, 223-231 (1932).

<sup>2</sup> H. Ramage, Spectrographic chemical analysis. Nature, vol. 123, 601-602 (1929).

<sup>3</sup> F. C. Steward and J. C. Martin, *op. cit.*



concentration is not balanced by a similar increase in potassium but is mainly accounted for by sodium.

All three species examined (*V. ventricosa*, *V. macrophysa*, *V. ocellata*) were found to contain rubidium normally in their sap in concentrations greater than in the sea. Precise determination of the accumulation ratio has yet to be made, but this seems to be less than that for potassium. In view of the extreme dilution of rubidium in the sea and since dilution tends to increase the accumulation ratio, this result indicates that the tendency of rubidium to accumulate is inherently less than that of potassium. The rubidium normally present in the sap could be neglected when this element was absorbed from sea water enriched with rubidium salts.

The experiments demanded that samples of *Valonia* should be exposed for long periods to sea water which contained lithium, rubidium, and caesium salts and was renewed infrequently if at all. In the dark, or light of very low intensity, clean *V. ventricosa* contained in glass vessels with a large air space and a loose cover remained in perfect condition for several weeks (e.g. 51 days). Under similar conditions the longevity of specimens attached to coral fragments was relatively short owing to bacterial activity. Both *V. macrophysa* and *V. ventricosa* survive admirably in bright sunlight with suitable precautions. Experiments in the light were conducted in bottles only half filled with liquid and submerged in the sea at a depth of 10 to 15 feet in a locality such that they were unshaded and received at noon 50 per cent of the vertical component of the incident light at the surface. *Valonia macrophysa* was more tolerant of this treatment than *V. ventricosa*. For long experiments it was found necessary to open daily the bottles which contained *V. ventricosa* to air, and so this was done for all cultures. The mechanical effects of surf were eliminated by fastening the culture vessels rigidly to heavily weighted "cradles."

In all cases rubidium was much more readily absorbed than either lithium or caesium. In external solutions having the same lithium, rubidium, and caesium concentration the sap concentrations in lithium and caesium were of the same order, whereas the rubidium concentration attained frequently exceeded these by over ten times.

According to the few results of Brooks,<sup>1</sup> *V. ventricosa* rapidly absorbed and accumulated rubidium and attained high concentrations in sap and protoplasm which were unaffected by time. Numerous experiments in which time curves were obtained all yielded a different result. Rubidium increased slowly but progressively in the sap for many days. After 51 days in diffuse light of low intensity and sea water containing 0.011 eqvls., the concentration of rubidium in the sap of *V. ventricosa* was somewhat greater than 0.02 eqvls. per liter.

In bright light the concentration of rubidium as of other ions entering the sap was very much increased. Even so the large vesicles again behaved as systems relatively inactive in salt accumulation.

The work of Brooks<sup>2</sup> indicated a possibility that where only low concen-

<sup>1</sup> S. C. Brooks, *op. cit.*

<sup>2</sup> S. C. Brooks, The accumulation of ions; relations between protoplasm and sap in *Valonia*. Jour. Cell. and Comp. Physiol., vol. 6, 169-180 (1935).



trations of rubidium were observed in the sap, high concentrations obtained in the protoplasm. Brooks' evidence was indirect. It is true that the concentration of the alkali metals investigated may be somewhat greater (order of twice) in the protoplasm than in the sap, but the very high and physically improbable concentrations of rubidium postulated by Brooks were never realized in our experiments. Brooks' results seem to be due to the unreliable method he employed for the determination of rubidium.

The small vesicles attained higher concentrations of lithium, rubidium, and caesium than the large ones. Consequently a large graded stock of very small vesicles of *V. ventricosa* (in the smallest class 1 gm. fresh weight = 500 to 600 vesicles) was obtained from Bush Key Reef. Although more active than larger vesicles, even these did not absorb the elements supplied with great rapidity. It was concluded that some other factor limited their activity. Experiments dismissed the plausible hypothesis that the attached plants of *V. ventricosa* possess salt-absorbing properties of a much greater magnitude than the unattached, and it seemed that nutritional factors alone could be responsible for the sluggish absorption of these very small vesicles. Experiments were therefore carried out using three species of *Valonia*, which were exposed to sea water plus lithium, rubidium, and caesium salts to determine the effect of light and added nitrate and phosphate (which in sea water in contact with a rich flora and fauna may fall to a very low level) on the uptake of the alkali metals.

The fact that light and an increased supply of nitrate and phosphate increase both penetration and accumulation was conclusively demonstrated. It was also noted that the addition of nitrate and phosphate to sea water markedly stimulated the growth of hapteron and rhizoidal cells on these small vesicles. The importance of these factors and of the size of the vesicle in the salt absorption of *Valonia* emphasizes the intimate relationship between the uptake of cations and the vital processes of these plants. This tends to harmonize the special case of *Valonia* with the conclusions derived from many other plants which have been investigated from this point of view.

It is evident that only culture experiments can reveal the full nutritional requirements of *Valonia* alike for growth and for salt accumulation, and these should be determined as a prelude to further work on this organism. Culture experiments on material successfully transported from Tortugas to Birkbeck College are contemplated, as well as ultimate analyses of samples of *Valonia* which were collected at different stages of their growth at Tortugas.

*The Effect of Irradiation of Lytechinus Eggs in Various Dyes with Sunlight,*  
by D. H. Tennent

The work reported in Year Books Nos. 34 and 35 was based on a study of fertilized eggs placed in dye solutions and irradiated; the work here reported was based on the examination of unfertilized eggs placed in solutions of dyes, irradiated, and inseminated after irradiation. This technique gave results, especially with acid dyes, that had not been obtained before.

Following irradiation of the unfertilized egg in fluorescein and in eosin Y, pitting of the surface of the egg and vacuolization, with the formation of

refrangent bodies in the vacuoles, occurred. Cytolysis was usually restricted to one region of the egg and was of the blister type. Fertilized eggs with well-separated fertilization membranes, irradiated in solutions of these dyes, of the same strength, showed no effects of the treatment.

After irradiation of unfertilized eggs in thionin, similar vacuolization occurred.

A prolonged study of the effects of irradiation on eggs in brilliant green in concentrations of from 1:1,600,000 to 1:400,000 showed striking contrasts in types of cytolysis. This study, together with that made on uninseminated *Lytechinus* eggs irradiated in solutions of neutral red and never inseminated, and with results already reported, give a complete picture of the cytolysis appearing as a photodynamic effect.

The study of eggs irradiated in acridine revealed many cases of nuclear division without cytoplasmic division, and of failure of the egg and sperm nuclei to unite after insemination.

Further studies on irradiation in solutions of picric acid, basic fuchsin, auramine O, mixtures of auramine O and neutral red, Congo red, cresyl violet, rhodamine B, and pyronin were also made.

It may be said in general that eggs irradiated in dye solutions prior to insemination underwent surface changes that prevented the separation of the fertilization membrane.

In addition to the work described above, a study of the effects of duration of irradiation and of increased temperature during irradiation was made.



# GEOPHYSICAL LABORATORY<sup>1</sup>

L. H. ADAMS, ACTING DIRECTOR

Prior to the establishment of the Geophysical Laboratory there had been little opportunity to make exact measurements on the formation of the minerals that make up the crust of the Earth. Just what happened when a crystalline rock melted, or when a molten magma solidified, was largely a matter of conjecture. Volcanic outbursts, world-shaking earthquakes, and other phenomena having to the untrained mind a hint of the supernatural, resisted explanation because of the lack of experimental facts. The segregation of ores and minerals, so necessary for the well-being and higher civilization of mankind, involved properties and processes of which little was known. The purpose of this Laboratory since its beginning has been to study and to measure the factors that enter into the formation of rocks and the other materials of the Earth. Although there have been some changes in scope and methods, the general objective continues to be the determination, with all the precision that may be possible, of the underlying causes of geologic and geophysical phenomena.

Upon encountering a broad problem in geology, it appears necessary first to formulate it in terms of a series of sharply defined problems in physics and chemistry. Adherence to this procedure is based on the conviction that the present condition of the Earth, however it may have been attained, is the result of orderly processes which, except in magnitude of space and time, have their exact counterpart in experiments that can be performed at will in the laboratory. Whatever success the Laboratory may have achieved in experimental geology has resulted from the adherence to the quantitative method of approach and a recognition of the necessity of measuring simple factors. In this as in other branches of science a major purpose is the discovery of generalizations or "laws" which, by presenting a vast array of information in a compact and usable form, make it possible for the human mind to comprehend matters of forbidding complexity and even to predict the course of processes that have not yet been subjected to measurement.

Progress in geophysical investigations requires a judicious combination of field work and laboratory experimentation. On the laboratory side a study of the melting temperatures of mixtures containing the important rock-forming minerals has been carried forward successfully during the year. The systems containing alkali-alumina silicates have proved to be of unusual interest. It has already been established that in the solidification of molten mixtures containing the feldspathoid, leucite, with silica and either diopside or anorthite, the diopside or anorthite is first removed nearly completely by crystallization, leaving a residual liquid of nearly pure alkali-alumina silicate. The alkali-alumina systems are remarkable also for the length of time required for their investigation. Owing to the slowness with which the crystallization of the materials proceeds, the separate researches may require five years or more for completion. The effect of water as an ingredient of silicate melts is now receiving more active attention. Among the significant

<sup>1</sup> Situated in Washington, District of Columbia.



results already obtained with a new apparatus for quenching silicate mixtures in steam under pressure is the establishment of the temperature at which analcite is transformed to albite. With a starting material intermediate in composition between analcite and albite this temperature is 385° C. Other investigations with an apparatus that develops pressure corresponding to a depth of 13 km., or 8 miles, below the surface of the Earth have shown that the melting point of albite in the presence of water is lowered from 1125° C. to 810° C. at 3000 atmospheres.

The completion of the exhaustive investigation on the sulfides of copper and iron marks a distinct advance in our knowledge of sulfide ores. The minerals pyrite, pyrrhotite, chalcopyrite, bornite, cubanite, chalcocite, and covellite have been prepared synthetically and their mutual relations established by means of their dissociation pressures. A study of the telluride minerals calaverite, krennerite, and sylvanite has proceeded in two principal directions: modern X-ray methods have yielded a more exact comparison between the internal arrangement of the atoms and the external crystal form than had been previously possible; and, by means of the reflecting microscope, advances in determinative technique have made it feasible to ascertain in hand specimens the relative abundance of the minerals and to establish their order of deposition.

Field studies and related laboratory investigations have covered a variety of interesting regions. Special mention should be made of the study of volcanic activity in Guatemala and El Salvador, which has thrown light on the chemical aspects of volcanism and has demonstrated the remarkable amount of hydrofluoric acid contained in some volcanic gases; the investigation of rocks from Antarctica, collected by the Second Byrd Antarctic Expedition, which showed some unusual features and have lent themselves well to a careful measurement of the separate compositions of groundmass and phenocrysts; the securing of additional cores from the ocean bottom at depths greater than had been reached previously; and the measurement of gravity with a new portable apparatus, sensitive to one part in a million, which has shown the existence of striking differences in gravity over small distances along the surface.

The following outline presents further details concerning the work recently completed or now in progress.

## EQUILIBRIUM RELATIONS IN SILICATE SYSTEMS

### SYSTEMS WITHOUT WATER

Studies on the melting phenomena in mixtures of rock-forming minerals are being actively continued, with the expectation that the results will supply the answer to an increasing number of petrologic questions. Of especial interest is the melting behavior of (a) the olivines and pyroxenes (particularly those containing iron oxide), because they are among the first minerals to crystallize from a cooling magma, and (b) the alkali-alumina silicates, which are among the last minerals to crystallize.

*Composition of rock-forming pyroxenes.*—These metasilicates of calcium,

magnesium, and ferrous iron are among the most important minerals of igneous rocks. They are complicated solid solutions existing in several different crystalline modifications whose temperature-stability relations and chemical compositions play an important part in the progress of crystallization of a rock magma. Our attention has been confined mainly to those metasilicate pyroxenes whose compositions lie in the triangle represented in figure 1, which depicts graphically the systems and compounds involved in this part of the program.

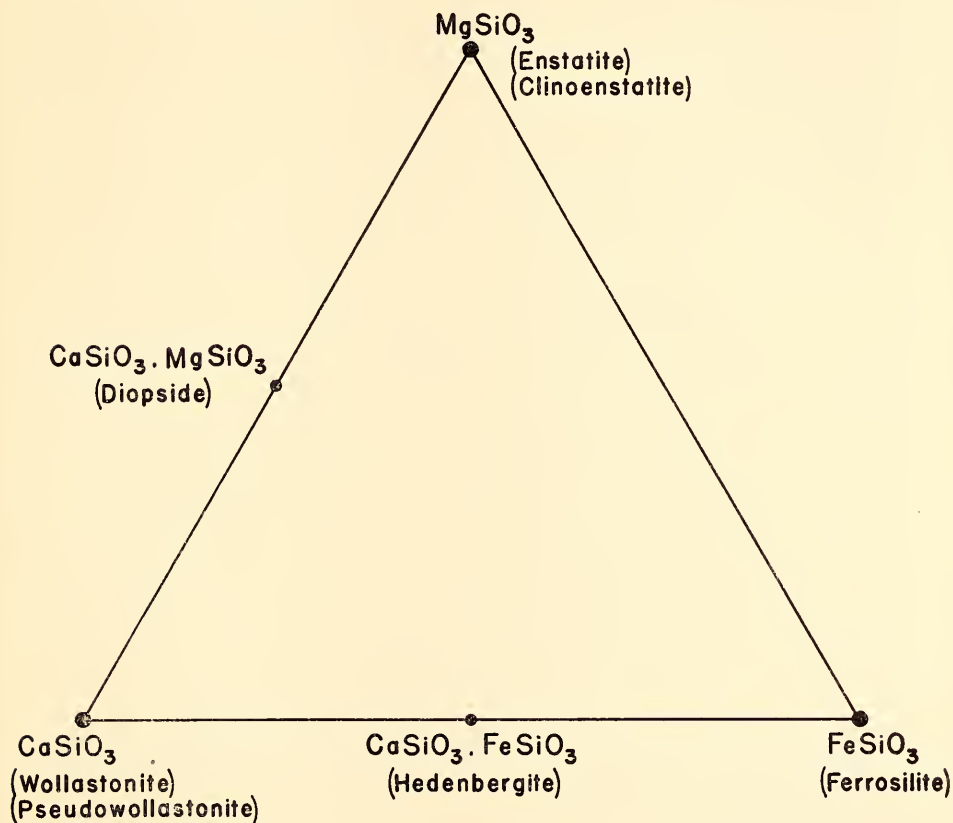


FIG. 1—A study of the early-crystallizing minerals of igneous rocks required the investigation of the melting relations of the pyroxenes whose composition is represented in this triangular diagram.

The first step in the investigation was an accurate determination of the behavior of mixtures represented by the side lines of the triangle. Complete data for the join  $\text{CaSiO}_3$ - $\text{FeSiO}_3$  and for the join  $\text{MgSiO}_3$ - $\text{FeSiO}_3$  have already been published by Bowen and Schairer. The system  $\text{CaSiO}_3$ - $\text{MgSiO}_3$ - $\text{MgSiO}_3$  (a portion of the  $\text{CaSiO}_3$ - $\text{MgSiO}_3$  side of the triangle in figure 1) was investigated a number of years ago by Bowen and the remainder of the

same side line was studied by Ferguson and Merwin. Recent investigations by Schairer and Bowen have led to a revision of this latter system.

*Melting relations of the alkali-alumina silicates*—The system potash-alumina-silica is experimentally a very difficult one, principally because a long time is required for the crystallization of the samples. Already, studies on nearly 400 different compositions in this system have been made by Schairer and Bowen. The investigation is about three-quarters finished and is being vigorously pressed to completion.

The system soda-alumina-silica is also a difficult one. Data for this system depict the complete stability relations of the important rock-forming minerals albite and nepheline and throw light on the origin of the corundum-bearing nepheline-syenites. Like the preceding system, it involves a large amount of labor, but will probably be completed before the end of the year.

A part of the system leucite-silica is practically impossible to work out directly, because apparently most of the mixtures (if free from water) cannot be made to crystallize even after a lapse of several years. On the other hand it has proved feasible to establish the melting relations for this system by extrapolation from the data for the ternary system potash-alumina-silica.

The ternary system kaliophilite-nepheline-silica may be considered to be represented as a diagonal plane through the quaternary tetrahedron potash-soda-alumina-silica. The results obtained for this system show us the mutual relations of the common and important feldspathoids, leucite and nepheline, the two alkali feldspars, orthoclase and albite, and the several forms of silica. Work on this system has been in progress about eight years, and at least four more years will be required to complete it. The fact that it sometimes takes as long as two years to crystallize a single sample necessarily prevents rapid completion. This system is probably the most difficult and at the same time the most interesting one that has been studied at the Geophysical Laboratory. Bowen has aptly called it "petrogeny's residua system." It involves a ternary solid solution series and also a binary solid solution series, which are of theoretical as well as practical interest. A preliminary report on this system has been published by Schairer and Bowen and has been of value in connection with some important problems of petrology. The completed system will be a necessary foundation for important investigations on silicate systems containing water as one component.

*Combination of early-crystallizing minerals with late-crystallizing alkali-alumina silicates*—The composition of the residual liquids left after fractional crystallization of rock magmas is of great interest. In order to investigate these compositions it is necessary to make various combinations of early-crystallizing and late-crystallizing components. Some of the more important of these combinations are shown diagrammatically in figure 2. The system leucite-diopside-silica has just been completed by Schairer and Bowen. The data show that for any melt within this system the diopside is first removed almost quantitatively by crystallization, leaving a residual liquid very rich in alkali-alumina silicates.

Measurements on the system leucite-anorthite-silica are about 80 per cent completed. The remaining 20 per cent involve mixtures that are particularly difficult to crystallize. Completion will be determined by the length of time

required for the crystallization of the various mixtures. The progress made already is sufficient to show that in this system anorthite is removed nearly completely by crystallization, leaving a residual liquid quite rich in alkali-alumina silicates.

Mixtures of nepheline, diopside, and silica do not form a ternary system, and are complicated by the appearance of olivine, plagioclase, complex nepheline-anorthite solid solutions on the liquidus surface, and melilite at

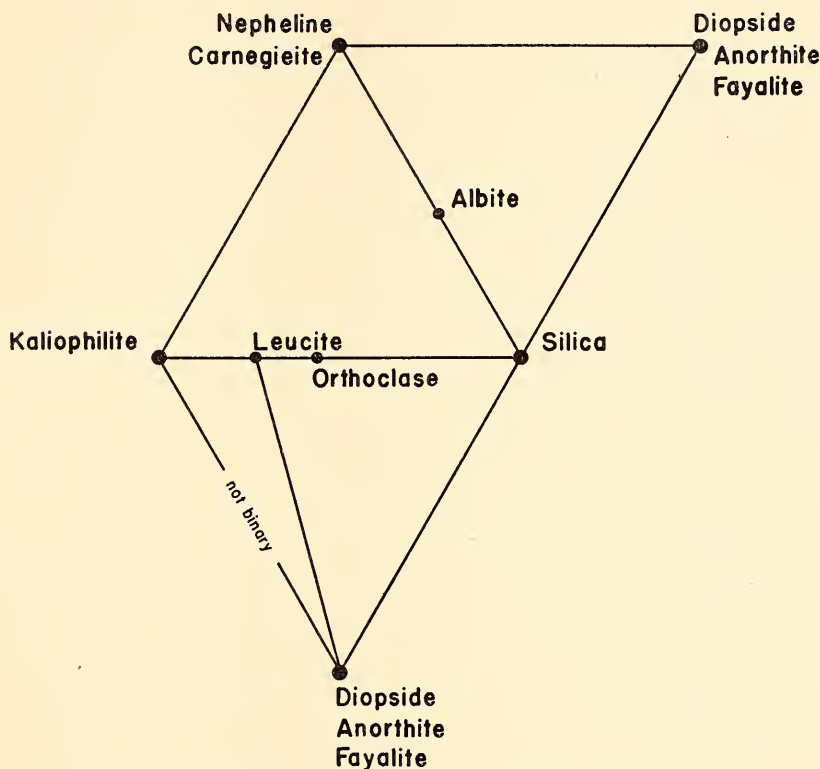


FIG. 2—Diagram showing interrelation of systems involving both early- and late-crystallizing minerals.

sub-liquidus temperatures. Some studies on these mixtures are being made by Schairer.

The system nepheline-fayalite-silica has been completed by Bowen and Schairer and accepted for publication. The data show that for melts within this system the residual liquids left after crystallization are rich in alkali-alumina silicates and suggest the origin of fayalite-trachytes and fayalite-phonolites. A general discussion of residual liquids and their importance in petrology, based on the results for this and other systems, has been given by Bowen (Laboratory Paper No. 916).



A large part of the system nepheline-forsterite-silica has been worked out by Greig. Measurements on the important binary system nepheline-albite, which is a part of this ternary system, have been completed, but work on the ternary system has been delayed on account of the necessity of obtaining better temperature regulation in the low-temperature region close to the albite field. A large number of measurements have also been made by Greig on the system anorthite-diopside-silica.

*Alkali silicates*—Simple systems containing only silica and an alkali are not found in ordinary rocks, but the alkali silicates afford an opportunity for a study of the physical-chemical relations in silicate magmas, and are, moreover, important end members in more complicated silicate systems. Earlier work on the system soda-potash-silica has been supplemented by a recent study by Kracek, Bowen, and Morey of the system potassium metasilicate-silica. A study has also been made by Kracek of the system potassium disilicate-sodium disilicate at the liquidus and in the solid phases below the liquidus. Numerous polymorphic inversions and series of solid solutions make the relations complex. The ternary system sodium metasilicate-lithium metasilicate-silica is being investigated by Kracek. In this system compositions near the liquidus boundary for the quartz-tridymite transformation have been found useful for establishing the quartz-tridymite inversion with a precision of  $\pm 2^\circ$ . Some work has also been done on the binary systems of silica with the oxides of rubidium and caesium. The completion of these binary systems will provide us with an interesting and instructive comparison of the various alkali silicates.

*Melting of natural rocks*—Some preliminary measurements were previously published by Greig, Shepherd, and Merwin on the melting of a number of naturally occurring rocks. Contrary to the commonly accepted opinion, it was established that granites melted at higher temperatures than basalts. Additional measurements have been made, and plans have been made for a continuation of this line of investigation using a series of basalts obtained from one locality and probably genetically related to one another.

*New studies now being initiated*—To obtain some notion of the rôle of alumina in natural augites, exploratory studies are being made on mixtures of fayalite and anorthite, of fayalite and alumina, and of iron oxide and alumina. Work has also been started by Schairer on the ternary system nepheline-anorthite-silica. In dealing with the origin of certain rocks through the assimilation of sediments or metamorphic schists by a hot magma coming from depth, it is essential to know more of systems containing alumina as one component. More specifically, we need additional data on the quaternary system lime-magnesia-alumina-silica, and it is hoped that progress can be made in this direction.

#### SYSTEMS WITH WATER AND OTHER VOLATILE COMPONENTS

*Moderate pressures*—Morey and Ingerson have been developing an apparatus for quenching silicate mixtures in steam under pressure. In this work a number of unexpected minor problems have been encountered, but most of them have been solved. Some experiments have been made upon the sta-

bility relations of analcite and albite in the presence of water. The starting material was an artificial gel having the composition of a hydrous aluminum silicate. It appears that there is a fairly definite temperature above which albite is formed and below which analcite appears. Experiments made with crystalline albite and with albite glass were less satisfactory.

Boric oxide as a component in aqueous silicate systems offers features of much interest. Work is being done by Morey on the ternary system soda-silica-boric oxide. Great difficulties in obtaining crystalline preparations are encountered over a considerable part of this system. In the study of the binary system water-boric oxide by Morey and Kracek a large amount of work has been done, and several puzzling features have been cleared up. The four-component system consisting of alumina, silica, water, and either soda or potash is being investigated by Morey and Burlew. Vapor pressure as a function of composition and temperature is determined, and compositions are measured by filtering the aqueous solution after equilibrium has been attained in a bomb and then analyzing the filtrate. We have here two different methods of attack. By quenching in steam we start at the liquidus surface, and work down with increasing water pressure. In the use of the bomb we start in the middle. In either case it is of course necessary for equilibrium to be attained. The two methods supplement each other satisfactorily. For example, mixtures on the join between  $\text{Na}_2\text{O} \cdot \text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2$  (the proportions of these components in analcite) and the sodium disilicate-quartz eutectic can be followed into the ternary system to a considerable distance by the use of the bomb. This ties in effectively with the work at lower temperatures and with the quenching experiments.

An investigation of the distribution of two volatile components (water and carbon dioxide) between the liquid and vapor phases is being carried out by Morey and Fleischer. Attempts to determine the composition of the phases at equilibrium by quenching the mixture in a small bomb did not lead to conclusive results, because mixtures low in silica and high in carbon dioxide could not be quenched satisfactorily. More recently a two-compartment bomb with valves for separating the phases has been built and is being used successfully.

Measurements on the vapor pressures of various saturated solutions are being carried out by Kracek, who has also been determining the equilibrium relations among the hydrates of copper sulfate, and the vapor-pressure and composition relations for water-ammonia at moderate pressures.

*High pressures*—In the investigations already mentioned the rôle of pressure is mainly that of holding the water and other volatile components in the silicate solution. The pressure is not large; usually it is of the order of a few hundred atmospheres or less, and by itself has little effect. At depths that are well within what is called the crust of the Earth, pressures of many thousands of atmospheres are encountered and such pressures exercise per se an important influence on the melting phenomena of silicates and the character of the reactions that take place. In order to obtain a complete picture of the processes taking place in the formation of igneous rocks, it is necessary to investigate systems that involve, not only high temperatures and the presence of water, but also high pressures. With an apparatus that permits us to

subject silicates in the presence of water simultaneously to a temperature of 1000° C. and a pressure of 4000 atmospheres, a beginning has already been made in this field of investigation. Measurements on the solubility of water in granite glass and albite glass have already been reported upon. Goranson has now completed the measurements on the system orthoclase-water and albite-water at pressures up to 4000 atmospheres, determining not only the solubility of water in the molten silicate at various pressures but also the temperature-pressure freezing-point curves. The system orthoclase-water is not a binary one, because at atmospheric pressure orthoclase melts incongruently to leucite and liquid. In the presence of a second phase (water-rich) the melting point of the leucite decreases rapidly with increasing pressure, whereas the transition orthoclase-leucite changes relatively little with pressure. The two curves intersect at about 2000 atmospheres, above which orthoclase melts congruently. On the pressure-temperature diagram the leucite field is thus strictly limited in extent. The system albite-water is binary, and with increasing pressure the melting curve falls steadily but with decreasing slope.

#### EQUILIBRIUM RELATIONS IN SULFIDE SYSTEMS

Sulfide minerals play an important part in connection with ore deposits. The system copper-iron-sulfur recently completed and published by Merwin and Lombard presents a comprehensive view of the relations between the various copper and iron sulfides. Light is shed on the relations and properties of sulfide minerals by a study of compounds containing the related element tellurium. An investigation of gold-silver tellurides is referred to in a later section.

#### BEHAVIOR OF MINERALS AND SYSTEMS UNDER HIGH HYDROSTATIC PRESSURE

##### EQUILIBRIUM IN BINARY SYSTEMS

As mentioned above, it is necessary in studying the processes involved in the formation of the Earth's crust to take pressure as well as temperature into account. Progress in this difficult field of experimentation is slow, but our knowledge is being advanced in three principal directions: first, by the determinations of equilibrium in aqueous silicate melts in the high-pressure, high-temperature, gas-filled bomb already referred to (Goranson); second, by the determination, for simple binary systems, of freezing point-solubility curves at much higher pressures but at lower temperatures (Adams); and third, by measuring accurately the properties of solutions at moderate pressures, and then by various devices extrapolating the data to higher pressures (Gibson). In all this work much help is obtained by applying the principles of thermodynamics. Perhaps in no other field of investigation can simple thermodynamic relations be used so advantageously. As in the past, considerable attention has been given to the development of experimental methods and to improvements in technique.



## ELASTICITY OF SOLIDS

By the use of high hydrostatic pressure the bulk modulus of rocks and minerals can be measured with satisfactory precision. Such measurements, in combination with seismologic data, have added to our information concerning the interior of the Earth. This type of investigation is being continued and additional measurements on typical rocks, more especially a series of granites, are being made. The new results already obtained supplement and confirm the earlier determinations.

## CONSTITUTION OF SOLUTIONS

## DETERMINATION OF VOLUME CHANGES

Viewed in a broad way, the problems in the Geophysical Laboratory are largely those of silicate solutions. In order to determine the behavior of solutions under extreme conditions of pressure and temperature, we require a knowledge of the physical-chemical principles involved in solubility and rate of reaction. A fruitful field of investigation has been found in the study of the volume changes of typical solutions when subjected to changes of temperature and pressure. It has been found possible to make measurements with high precision on the compressibilities and thermal expansibilities of a large number of solutions. Some of the important questions to be answered have been: (1) What general relations exist for different types of solutions among the compressibilities, the thermal expansibilities, and the densities, or between these and any other easily measurable property of the solution? (2) Can we find any empirical generalization that will enable us to predict quantitatively these properties of solutions once the requisite properties of the pure components are known? (3) What general methods are available for extending results obtained experimentally over a given range of pressure, temperature, or concentration, to provide accurate estimates of the properties over a much larger range? These problems have been attacked empirically by determination of the behavior under pressure of a number of solutions that can be readily handled as liquids at ordinary temperatures, and by subsequent analysis of the results in the light of modern physical chemistry. The preliminary investigation has been limited to solutions of salts with water and with various organic solvents. It is expected that ultimately the results and generalizations may be applied to silicate mixtures.

In the course of the work an apparatus has been developed in which visual observations may be made on a system under pressure, the temperature being accurately controlled. The apparatus has made it possible to measure volume changes speedily and with much higher precision than had been hitherto attainable.

By the help of generalizations that we have found to exist, the results may be put in a mathematical form which enables us to say under what circumstances the solubility of a given solid in a liquid will increase or decrease with pressure. Strong interaction between the components of a solu-



tion, a very compressible solvent, low pressure, or a small solubility at ordinary pressure, will in general tend to make the solubility of a solid increase with pressure. The opposite of the named conditions favors a decreasing solubility. We may predict, therefore, that in silicate magmas the solid components will in general be less soluble under high pressure than at atmospheric pressure (the temperature remaining constant). We also reach the important conclusion that solids such as carbonates, sulfates, or sulfides, whose aqueous solutions abound in nature, will be significantly more soluble under a pressure of 1000 atmospheres than they are at ordinary pressure.

Other deductions concerning the sizes of ions and their influence in separating the molecules of a solvent have been found to have important applications in connection with other solution phenomena such as the "salting-out effect," which has a considerable biological interest.

#### RAMAN EFFECT

Another promising approach to the constitution of solutions is afforded by studies on the Raman effect. The spectrum of lines formed by light scattered from transparent materials is closely related to the system of absorption bands of the material, and yields information concerning the vibrations of the constituent molecules and the arrangement of the atoms within the molecule. It appears that by measurement of the wave lengths, or frequencies, of the Raman lines many anomalies in physical properties such as viscosity, vapor pressure, and energy of activation may be explained, and light is shed on such phenomena as ionization, common ion effect, and the formation of complex compounds.

Measurements were made first on simple liquid organic compounds because the constitution of these substances is better known than that of inorganic compounds. The results obtained by Hibben led to the interesting conclusion that some of the accepted formulæ were incorrect. Subsequently, inorganic compounds such as nitrates, sulfates, and halides were studied both in solution and as crystals. The results give evidence as to the type of valence binding, that is, whether it is ionic or homopolar. The common ion effect in solution of two soluble salts was observed directly for the first time and complex compound formation in solution was demonstrated. A recent study of water gives evidence of the existence of intermolecular forces that hinder the rotation and vibration of the water molecules and that are doubtless connected with the peculiar behavior of these anomalous substances.

The investigation of silicate glasses is difficult because the Raman lines are not sharp. Probably, as in the case of water, this lack of sharpness is due to hindered rotation. There is a striking difference in the Raman lines yielded by quartz and by silicate glass; the former gives sharp lines, while the latter gives broad diffuse lines that are difficult to measure. Silicate glasses have been shown to have some molecular vibrations similar to those occurring in quartz, but it appears that these glasses have a continuing structure similar to that of the organic glasses.

### CRYSTAL STRUCTURE

Roentgenographic methods continue to provide an indispensable tool for many of the researches on silicates and other compounds. Such methods have been especially useful in the investigation of the minerals calaverite, krennerite, and sylvanite.

These three tellurides of gold and silver, which are important ore constituents at Cripple Creek, Colorado, and Kalgoorlie, Australia, have been studied by Tunell and Ksanda with the X-ray goniometer, the reflection goniometer, and the reflecting microscope. The space groups to which they belong have been determined and their detailed atomic arrangements have been established. A more close and exact correlation of the internal structure and external crystal form has been accomplished than anything attempted heretofore, and as a result, new light has been thrown on the complex and obscure problem presented by the unusual form development of one of these minerals, calaverite, which has puzzled crystallographers for more than thirty years.

Criteria have been developed by us which permit the differentiation of the gold and silver tellurides in hand specimens. Criteria have also been developed (by J. S. Vhay, of the U. S. Geological Survey, and M. N. Short, of the University of Arizona, in collaboration with us) for differentiating them under the reflecting microscope in polished surfaces. These advances in determinative technique made possible a paragenetic study of the ores at Cripple Creek, Colorado (in collaboration with G. F. Loughlin and A. H. Koschmann, of the U. S. Geological Survey, who have been investigating the field relations at Cripple Creek for several years). Previously it was not possible to determine the relative abundance of the valuable minerals, but this has now been accomplished (in collaboration with Loughlin and Koschmann). The relations of the ore minerals and their order of deposition have also been established, and some views previously held in this connection have been proved incorrect.

Measurements on a number of other materials have been made by Tunell and Ksanda. Preliminary work on brochantite,  $\text{CuSO}_4 \cdot 3\text{Cu}(\text{OH})_2$ , for the purpose of determining whether the symmetry although externally orthorhombic is really structurally monoclinic, has been started. During the past year we have cooperated in studies undertaken by members of the U. S. Geological Survey and have identified numerous minerals by their X-ray powder spectra.

Installation of a new source of high tension has recently been completed. The transformer delivers 50 to 100 kv. with full-wave rectification. With this important improvement more satisfactory spectrograms will be obtained and the apparatus will be convenient for use with an ionization chamber X-ray goniometer for measuring the absolute intensities of the reflections.

### GASES IN ROCKS

The gas content of rocks has an important bearing on the condition of the magma from which the rocks were formed, and is closely related to laboratory problems on aqueo-igneous fusion. Shepherd has made numer-

ous determinations on the gases which can be extracted from rocks by heating in a vacuum. The gases are the same in character and approximately the same in order of abundance as are found in the gaseous emanations from volcanoes which we have investigated through our own collections and with the valuable cooperation of Frank A. Perret and T. A. Jaggar. The chief constituent of a volatile material is water, and it is partly for this reason that in our laboratory work we have given a prominent place to water in the investigations on silicate equilibria in the presence of volatile components. Considerable attention has been given to the behavior of obsidians and pitchstones when heated, and an attempt is being made to connect their properties with the results on the solubility of water in silicate melts under pressure, mentioned above.

### MAGNETIC PHENOMENA

In connection with one of the important problems in geophysics, namely the question of the source of the Earth's magnetism, we have endeavored to obtain more information concerning the physical behavior of ferromagnetic substances. The method of attack is to correlate the magnetic behavior of various materials with their composition and structural arrangement. For a number of spinels Posnjak has determined the effect on the susceptibility and Curie temperature of the substitution of definite atoms in the crystal lattice. This work is being continued, and other studies of the effect of pressure on the Curie point and on the thermal expansion of ferromagnetic substances are in progress.

### THERMAL PROPERTIES

In order to prepare for obtaining measurements rapidly but with adequate precision, a new and improved experimental arrangement has been set up by Roberts. Either of two methods may be employed for measuring latent heats. In the first method a conventional calorimeter is used; the preferred method is that of the "furnace aneroid," in which the heat required to melt the charge is determined directly as it melts. The charge is hung in a furnace whose temperature and temperature distribution are closely controlled, and the heat supply to the charge is determined either by noting the lag in charge temperature behind that of the furnace or by supplying this heat from an electric heater embedded in the charge. The electric heater makes it possible, not only to determine heat input by the accurate electrical method, but to make a direct determination of the thermal leakage coefficient used to evaluate the net heat exchange between charge and furnace.

Important improvements in the new apparatus are (1) the use of a resistance thermometer wound with enamel-insulated copper wire for measuring temperatures, retaining the thermocouple for measuring temperature differences, and (2) the use of another resistance thermometer with a galvanometer and a photocell as a temperature regulator for the calorimeter bath.

## FIELD WORK AND RELATED LABORATORY STUDIES

## HYDROTHERMAL AND FUMAROLIC AREAS

An important series of igneous rocks, which Fenner collected in the hot-spring area of Yellowstone Park, are being studied by him in the laboratory for the purpose of supplementing and checking the field observations. In one area of the Park the mutual relations of the rocks were found to afford evidence upon a subject of controversy among petrologists, namely the possibility of a lava's being able to melt or dissolve large quantities of previously consolidated cold rock. In the Yellowstone occurrence there seems to be little doubt that a large amount of an older basalt has been melted or dissolved by a newer rhyolite. This circumstance has an important bearing on the fundamental properties of magmas and the functions they perform in Earth processes.

## VOLCANIC AREAS

Many samples of gas from the volcanoes of Java and Bali and also incrustations from these regions were collected by Zies and have been examined in the laboratory. The Javanese incrustations are particularly interesting because some are distinctly products of vapor-phase activity and others are formed from aqueous solutions. There are no notable concentrations of heavy metals such as were found in the Valley of Ten Thousand Smokes. The unusual concentration of tellurium and arsenic sulfide at Papandajan is an interesting case of differential concentration through vapor-phase activity.

Information has also been obtained by Zies on the chemical aspects of the volcanic activity in Guatemala and El Salvador. The gases that come into play are quite acidic, and consist of hydrofluoric acid, hydrochloric acid, and sulfur in various stages of oxidation. The high content of hydrofluoric acid is especially noteworthy.

## OCEAN-BOTTOM SAMPLING

Through the courtesy of the Woods Hole Oceanographic Institution another opportunity was afforded us to collect cores from the ocean bottom with the apparatus devised by Piggot. He succeeded in obtaining, from the vicinity of the Bartlett Deep, two cores over 6 feet long at depths of over 2700 fathoms, which is a somewhat greater depth than those at which he had previously been able to obtain cores. Additional valuable experience in operating the apparatus at considerable depths was secured.

Arrangements have been made to purchase a portable winch with Diesel engine and 5000 fathoms of cable. With this equipment we expect to continue the collection of cores from the ocean bottom and to reach still greater depths.

## PETROLOGICAL STUDIES

In 1929 the Institution sent an expedition to Central and East Africa which made possible an examination by Bowen of the volcanism associated



with the rifts and of the varied products of volcanism, and a study by Bailey Willis of the rift valleys and their tectonic relations. Since that time Bowen has studied in the laboratory, as opportunity arose, the large collection of lavas made in the field. These lavas have presented many problems concerning the crystallization of silicate magmas and have furnished the incentive for a number of high-temperature investigations of silicate equilibria, some of which are completed and others approaching completion. Several papers have been published dealing with the relations of some of the minerals of the lavas, and Bowen is now preparing a manuscript which gives a comprehensive description of the lavas and their chemistry, and also discusses their mode of origin in the light of their field relations and of the laboratory studies of silicate equilibrium carried out with these problems in mind.

An opportunity was afforded us to examine a series of Antarctic rocks collected by one of the exploring parties of the Second Byrd Antarctic Expedition. A number of specimens taken from the vicinity of an extinct volcano discovered by this party were brought to the Geophysical Laboratory for study. Examination of the specimens by Fenner showed some rather unusual features, which made it seem worth while to undertake a thorough microscopic and chemical study of the material. Of especial interest is a sample of ultrabasic rock, designated as an olivine fourchite. A careful determination of the relative amounts, as well as the chemical and mineral compositions, of the groundmass and phenocrysts has added to our knowledge of the process of crystallization in magmas.

#### MEASUREMENT OF GRAVITY

The gravity apparatus, devised by Wright, has been further developed by Wright and England, and is now yielding satisfactory results of great precision. The principle utilized in this instrument, namely the evaluation of the force of gravity at any point in terms of the deformation of an elastic solid, is quite simple, but it has taken some years to overcome the experimental difficulties and to produce an instrument and a method on which we can rely and which, in four minutes' measuring time, furnishes a value of gravity accurate to one part in one million.

In our instrument we use a spiral of tungsten wire, 4 mils thick and properly annealed and aged, mounted horizontally in a supporting frame. The wire spiral tapers from each end toward the center, at which a cross-boom of aluminum wire is mounted; to its outer end a small platinum bead is attached. The supporting frame is mounted on an axis to which a graduated circle, reading with vernier to 10", is attached. By rotating the frame in a clockwise direction the cross-boom of the spiral is brought to the horizontal position, and the reading on the graduated circle is recorded. The frame is then rotated in a counter-clockwise direction until the cross-boom of the spiral reaches the horizontal position on the opposite side, and the reading on the graduated circle is again recorded. The angular difference between these two positions is a measure of the relative gravity pull. The

tungsten spiral is made of such length and degree of taper that a change of one part in a million of the value of gravity will produce a difference of 10" in reading on the circle.

In order to reduce hysteresis and other disturbing elastic effects as much as possible, the spiral is maintained at a temperature constant to within  $0.02^{\circ}$  C., and under reduced air pressure of approximately 5 mm. of mercury. When the instrument is at rest the cross-boom of the spiral is maintained in a vertical position and the spiral itself is supported so that it is not under stress. Apparently this is the only one of the gravity torsion balances in which the spring is not continuously under load and in which there is not a shift of the zero point. The result of the combination of tapering spring with the cross-boom is to produce a system that is extremely sensitive near the upsetting position of the cross-boom, is not resonant to any period of vibration, and can be made to come quickly to rest without resort to any external damping mechanism.

In view of the satisfactory performance of the present gravity balance, we have designed and are now having constructed in the shop a new and improved gravity instrument which is to be much lighter in weight. Its castings are of an aluminum alloy, and the construction is to be more rigid; the heat insulation is to be more effective and designed for ice or electric thermostat control; a more effective leveling system is used; and a new type of illumination for circle, levels, and thermometers inside the instrument is to be adopted. The new instrument will enable us to occupy stations more rapidly and easily. It will be more easily portable and with it we shall be able to make a study of the gravity anomalies along the Atlantic seaboard within 100 or 200 miles of Washington. The results should have important bearing on the study of the continental shelf, the geological structure of the region, and its general isostatic adjustment.

Recently England has made a number of measurements in the vicinity of the District of Columbia. Some measurements taken at short intervals of distance show interesting localized differences in gravity. As an example, three results obtained along a north-south line may be cited. The first point was on River Road on Booth Creek, the second was 0.8 mile to the north, and the third an additional 0.6 mile to the north. The three values of gravity in gals were, respectively, 980.112, 980.119, and 980.116, and the respective "free air" anomalies were +46, +48, and +54 milligals.

#### SUMMARY OF PUBLISHED WORK

- (914) The studies in silicate chemistry of the Geophysical Laboratory of the Carnegie Institution of Washington. G. W. Morey. *Jour. Soc. Glass Tech.*, vol. 20 (Trans.), 245-256 (1936).

This paper, a contribution to the General Session of the International Congress on Glass, is a summary of the researches on phase equilibria in silicate systems carried out at the Geophysical Laboratory, with special reference to the application of these researches to geology and mineralogy, and to the progress which they represent toward the program of the Laboratory.

- (915) Phase equilibrium relationships in the binary system, sodium oxide-boric oxide, with some measurements of the optical properties of the glasses. G. W. Morey and H. E. Merwin. *Jour. Amer. Chem. Soc.*, vol. 53, 2243-2254 (1936).

In the system  $\text{Na}_2\text{O}-\text{B}_2\text{O}_3$ , the compounds  $2\text{Na}_2\text{O} \cdot \text{B}_2\text{O}_3$ ,  $\text{Na}_2\text{O} \cdot \text{B}_2\text{O}_3$ ,  $\text{Na}_2\text{O} \cdot 2\text{B}_2\text{O}_3$ ,  $\text{Na}_2\text{O} \cdot 3\text{B}_2\text{O}_3$ , and  $\text{Na}_2\text{O} \cdot 4\text{B}_2\text{O}_3$  are formed. The first of these, sodium orthoborate, is noteworthy for its low congruent melting point,  $625^\circ$ ; unexpected because in the system  $\text{Na}_2\text{O}-\text{SiO}_2$  the corresponding compound,  $2\text{Na}_2\text{O} \cdot \text{SiO}_2$ , melts incongruently at a high temperature. Pure sodium orthoborate fusions can be cooled to a glass, also an unexpected property. Sodium metaborate,  $\text{Na}_2\text{O} \cdot \text{B}_2\text{O}_3$ , which melts congruently at  $966^\circ$ , crystallizes so readily that it cannot be cooled to a glass. Sodium diborate,  $\text{Na}_2\text{O} \cdot 2\text{B}_2\text{O}_3$ , melts congruently at  $742.5^\circ$ , and occurs in three allotropic modifications, two of which appear to be monotropic. The composition range within which it is the primary phase is narrow, from 68 to 72.3 weight per cent  $\text{B}_2\text{O}_3$ . Sodium triborate,  $\text{Na}_2\text{O} \cdot 3\text{B}_2\text{O}_3$ , melts incongruently at  $766^\circ$ , and its stability field is from 72.3 to 76 weight per cent  $\text{B}_2\text{O}_3$ . Sodium tetraborate,  $\text{Na}_2\text{O} \cdot 4\text{B}_2\text{O}_3$ , which melts congruently at  $816^\circ$ , is the stable primary phase from 76 to greater than 99 per cent  $\text{B}_2\text{O}_3$ . There are two allotropic forms, one of which appears to be monotropic. It was the only crystalline phase to separate from a mixture containing 99.5 per cent  $\text{B}_2\text{O}_3$ , and all attempts to crystallize boric oxide itself met with failure. The optical properties of the crystalline sodium borates, and of some of the glasses, were measured.

- (916) Recent high-temperature research on silicates and its significance in igneous geology. Norman L. Bowen. *Amer. Jour. Sci.*, vol. 33, 1-21 (1937).

Of the various kinds of equilibria involved in the processes whereby diverse igneous rocks may have been derived from a common source, crystal  $\rightleftharpoons$  liquid equilibrium is usually regarded as important. Sufficient progress has been made in the laboratory study of silicate systems to indicate the nature of the final residual liquids from the fractional crystallization of complex silicate magmas. In each of six systems which have been investigated in detail and whose equilibrium diagrams are here presented, the residual liquid from fractional crystallization is enriched in alkali-alumina silicate, whether the other components of the systems are lime-alumina silicate, lime-magnesia silicate, or iron silicate. It is concluded, therefore, that in mixtures containing all of these ( $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$ , iron oxide,  $\text{CaO}$ ,  $\text{MgO}$ ,  $\text{Na}_2\text{O}$ , and  $\text{K}_2\text{O}$ ) the residual liquid from fractional crystallization will show this same character of great enrichment in alkali-alumina silicate. Since the oxides listed above make up some 97 per cent of the composition of the average igneous rock, the alkali-alumina silicate system ( $\text{NaAlSiO}_4$ - $\text{KAlSiO}_4$ - $\text{SiO}_2$ ) is here referred to as petrogeny's "residua" system. The equilibrium relations in this system have been investigated and the composition of those liquids having the lowest temperatures of crystallization has been found. The region embracing such liquids is represented by a well-defined valley in the fusion surface. If rocks very rich in alkali-alumina silicates are really formed from the residual liquids of fractional crystallization of complex magmas, they should be related in composition to the liquids lying in this valley of the "residua" system. Examination of the composition of 40 lavas (rhyolites, trachytes, and phonolites) from East Africa shows that they have such relationship in marked degree. The averages of world rhyolites, of trachytes, and of phonolites show a correspondence no less marked.

From these facts it is concluded that crystal  $\rightleftharpoons$  liquid equilibrium has been the dominant control in the production of rhyolites, trachytes, and phonolites, for the most part as residual liquids of crystallizing magmas.



- (917) The phase rule and heterogeneous equilibrium. George W. Morey. Article G in *Commentary on the scientific writings of J. Willard Gibbs*, vol. 1, 233-293, Yale Univ. Press, New Haven, Conn. (1936).

This article is one of a group written to elaborate and illustrate the thermodynamic methods of J. Willard Gibbs. It deals with the reasoning which has developed into that branch of science which considers the equilibrium between phases, solid, liquid, and gaseous, in systems of one to many components, a topic to which much of the work of the Geophysical Laboratory has been devoted. The subject is treated from the standpoint of the application of the equations deduced by Gibbs, in especial, of his equation 97:

$$vdp = \eta dt + m_1 d\mu_1 + m_2 d\mu_2 \dots + m_n d\mu_n.$$

The use of this equation in the several types of invariant, univariant, and divariant equilibria in systems of one, two, and three components is illustrated by examples.

- (918) The apparent volumes and thermal expansions of certain salts in aqueous solution between 20 and 40°. R. E. Gibson and John F. Kincaid. *Jour. Amer. Chem. Soc.*, vol. 59, 25-32 (1937).

In the course of the study of the correlation of the compressibilities with other thermodynamic properties of solutions it became necessary to obtain reliable values of the thermal expansions of solutions, and a survey of the literature revealed that such data were not abundant. Measurements were made, therefore, of the thermal expansions from 20° to 40° of aqueous solutions of barium chloride, potassium bromide, potassium nitrate, sodium iodide, and lithium bromide over the entire range of concentration, and incidentally the specific volumes at 25° of solutions of the three last-named salts were determined.

From these results apparent volumes, apparent expansions, and apparent expansibilities were computed and wherever possible expressed analytically as functions of temperature and concentration by simple formulæ. A new variable was found which sometimes replaces the volume concentration to advantage in the well-known equations connecting the apparent volume with the square root of the concentration.

The results indicated that the linear relation between apparent expansibilities and the square root of the concentration is fortuitous and not to be expected in general, as the complete relation is represented by a sigmoid curve. Contrary to recent allegations, no evidence requiring breaks in the curves of the apparent volumes or apparent expansions of lithium bromide solutions against the concentration at atmospheric pressure has been found.

- (919) A thermodynamic treatment of systems, in particular of solutions, from the point of view of activity and related functions. Roy W. Goranson. *Jour. Chem. Physics*, vol. 5, 107-112 (1937).

The purpose of this paper is to present a consistent treatment of solutions based on Lewis and Randall's definitions of activities and activity coefficients. Expressions are also derived for the fugacity and activity of a component in a gas mixture.

Line integrals had been adopted previously by the writer to express thermodynamic relations because they do not need to be supplemented by additional statements which could conceal ambiguities. Furthermore, such expressions give by inspection all the necessary relations such as derivatives, limits, etc. By employing line integrals here, the interrelations of activities and activity coefficients were obtained, in particular those for dissociated and undissociated solutes, which do not agree with some ideas appearing in the literature on this subject.



- (920) The melting of danburite: A study of liquid immiscibility in the system,  $\text{CaO-B}_2\text{O}_3\text{-SiO}_2$ . G. W. Morey and Earl Ingerson. *Amer. Mineral.*, vol. 22, 37-47 (1937).

It was found that danburite,  $\text{CaO.B}_2\text{O}_3.2\text{SiO}_2$ , melts incongruently at about  $1000^\circ\text{C}$ ., with the formation of two liquid layers. This behavior, together with the fact that there is a region of liquid immiscibility in each of the binary systems  $\text{CaO-SiO}_2$  and  $\text{CaO-B}_2\text{O}_3$ , suggested that there might be a band of immiscibility extending entirely across the ternary system  $\text{CaO-B}_2\text{O}_3\text{-SiO}_2$ . Such a region not only exists, but actually expands away from each of the two limiting systems, reaching a maximum of 38 per cent  $\text{CaO}$  at a ratio of approximately 40 per cent  $\text{B}_2\text{O}_3$  : 60 per cent  $\text{SiO}_2$ . This  $\text{CaO}$ -rich layer is heavier and less viscous than the other and so collects as a clear glass in the bottom of the crucible. The lighter liquid contains less than 0.25 per cent  $\text{CaO}$  and is so viscous that it never separates cleanly. The immiscible area decreases with increasing temperature, that is, the compositions of the two liquids tend to approach each other, and at a sufficiently high temperature it is possible that the two layers would disappear in the middle of the diagram, giving rise to two critical solutions and two separated regions of immiscibility.

The fields of the various crystalline phases which are adjacent to the area of immiscibility are outlined, the directions of the tie-lines are given, and temperatures are recorded on the phase-equilibrium diagram. There is a theoretical discussion of the relationships that must exist in the extremely small area between the  $\text{B}_2\text{O}_3\text{-SiO}_2$  join and the area of immiscibility.

Danburite could not be prepared by heating its components below its melting point, but its synthesis is possible by hydrothermal methods.

- (921) The Earth's interior, its nature and composition. Leason H. Adams. *Scientific Monthly*, vol. 44, 199-209 (1937).

The object of this communication was to summarize briefly the present notions concerning the Earth's interior and the steps by which the information has been obtained. Although the problem of the Earth's interior has not yet been solved, there has been a steady improvement in our knowledge of the subject. It is pointed out that further progress must come through the joint effort of investigators in the laboratory and in the field.

- (922) A note on ænigmatite. Norman L. Bowen. *Amer. Mineral.*, vol. 22, 139-140 (1937).

The refractive indices of ænigmatite in a pantelleritic lava from Lake Naivasha, East Africa, have been measured and found to be  $\alpha = 1.81 \pm 0.01$ ,  $\beta = 1.82 \pm 0.01$ , and  $\gamma = 1.88 \pm 0.015$ . Ænigmatites from a number of other localities have also been examined and the refractive indices are found to agree with the above values. Ænigmatite is therefore a mineral of high birefringence, contrary to the statements found in existing mineral tables.

- (923) The Raman spectra of water, aqueous solutions and ice. James H. Hibben. *Jour. Chem. Physics*, vol. 5, 166-172 (1937).

While water is one of the most common of the naturally occurring substances, until recently little has been accurately known about its molecular constitution, although it has long been assumed that the simple formula  $\text{H}_2\text{O}$  did not adequately explain its anomalous behavior in the liquid state. The Raman spectra of water and aqueous solutions demonstrate very concretely the existence of water complexes or a quasi-structural orientation of the molecules in the liquid. This interaction between the molecules is shown by a low-frequency oscillation near  $\Delta\tilde{\nu}$  150 which can be attributed only to definite forces—in addition to the ordinary van der Waals forces—acting between the molecular species. This is further substantiated by the appearance of

another Raman band near  $\Delta\tilde{\nu}$  450 arising from the hindered rotation of the hydrogen atoms. The intensity of these bands indicates that, at room temperature, a considerable fraction of the water molecules are bound together and that this fraction diminishes with increased temperature. Ordinary halide salts have no marked effect on this binding, but alkali hydroxides tend to diminish the "association." In ice, which is known to be made up of associated molecules, the frequencies  $\Delta\tilde{\nu}$  150 and 450 are displaced to  $\Delta\tilde{\nu}$  205 and 601 and appear with great intensity. A frequency occurring near  $\Delta\tilde{\nu}$  2100 is shown to be the result of a combination between  $\Delta\tilde{\nu}$  450 and the shift at  $\Delta\tilde{\nu}$  1627 which is due to the bending motion of the hydrogen atoms.

As both the chemical and physical properties of water are greatly modified by the degree of intermolecular binding, the Raman spectra observations have considerable utility.

(924) The system, Cu-Fe-S. H. E. Merwin and R. H. Lombard. *Econ. Geol.*, vol. 32, 203-284 (1937).

Reviewed in part in Year Book No. 30, pp. 82-84 (1930-1931) (Annual Report of the Director of the Geophysical Laboratory, Laboratory Publication No. 763).

For Cu, Fe, and S at temperatures not far below melting, the compounds lowest in sulfur are  $\text{Cu}_2\text{S}$  and  $\text{FeS}$ . Between these are: (1) considerable solid solution at the  $\text{Cu}_2\text{S}$  end, (2) a little solid solution at the  $\text{FeS}$  end, (3) mixtures of these solid solutions. The first effect of the absorption of more sulfur is the formation of sulfur-rich solid solutions,  $\text{Cu}_2(\text{Fe})\text{S}_{1+}$  (chalcocites) and  $\text{Fe}(\text{Cu}_2)\text{S}_{1+}$  (pyrrhotites); the second, the production of five ternary compounds, all of which are subject to solid solution; and the third, the formation of the two binary compounds covellite ( $\text{CuS}$ ) and pyrite ( $\text{FeS}_2$ ), which do not show appreciable solid solution, and are stable even in contact with saturated sulfur vapor over a wide range. Two of the ternary compounds,  $\text{Cu}_5\text{FeS}_6$  and  $\text{Cu}_3\text{Fe}_4\text{S}_6$  (?), are new. For some of these reactions the temperatures and pressures of sulfur vapor at a few pressures have been found, thus establishing dissociation pressure curves for  $\text{Cu}_5\text{FeS}_6$ ,  $\text{Cu}_5\text{FeS}_4$  (bornite),  $\text{CuFe}_2\text{S}_3$  (cubanite), and  $\text{CuFeS}_{1.94}$  (chalcopyrite solid solution).

At 455 mm. pressure of sulfur vapor on a triangular diagram of compositions, data obtained below the temperature of the beginning of melting of the sulfide powders and above the temperature of condensation of the sulfur were plotted, from which the following may be summarized. From many series of analytical compositions at particular temperatures isotherms were drawn. From changes in direction of the isotherms and from the solid phases present, fields containing the same phases were outlined. Fields of solid solution contain a single solid phase, and are crossed by slightly curved isotherms.

Between solid solutions that approach each other there are fields in which both solid solutions are present. In these fields the isotherms are subparallel straight lines joining the two compositions that are stable together. The temperature ranges in these (three) fields between solid solutions are: pyrrhotite-intermediate, about  $920^\circ$ - $675^\circ$ ; intermediate-chalcocite, about  $925^\circ$ - $550^\circ$ ; chalcocite- $\text{Cu}_{5+}\text{FeS}_{6+}$ ,  $484^\circ$ - $472^\circ$ .

Five other fields of two solid phases appear. They are between other parts of the boundaries of these solid solutions and the definite compounds pyrite and covellite. These fields are wedge-shaped. Two boundaries and the isotherms radiate as straight lines from the compounds.

In case three solid phases take part in a reaction, they are stable together in any proportions and at a single temperature. Thus, in the composition triangle the straight lines joining the compositions of the three reacting solids outline a triangular

isothermal field. Five such fields have been found at the following temperatures: 675°, 55°, 48°, 472°, 44°.

- (925) A view of magmatic differentiation. Clarence N. Fenner. *Jour. Geol.*, vol. 45, 158-168 (1937).

This paper was delivered at the Tercentenary Conference of Arts and Sciences at Harvard University, September 1936. It is a brief presentation of some of the major difficulties that are encountered in attempting to explain all the phenomena of differentiation of igneous magmas by a single process. Special attention is given to the theory of differentiation by crystal fractionation.

- (926) The apparent volumes and thermal expansions of certain salts in glycol and methanol. R. E. Gibson and John F. Kincaid. *Jour. Amer. Chem. Soc.*, vol. 59, 579-584 (1937).

The investigation of the thermal expansions of aqueous solutions mentioned in Paper No. 918 revealed specific effects of the different salts which seemed most readily explicable in their influence on the structure of the water itself. To confirm this opinion measurements of the apparent volumes and thermal expansions of some of these salts in solution in glycol and in methanol were made.

A comparison of the apparent and partial volumes of lithium bromide in water, glycol, and methanol solutions gives strong evidence that this salt influences the structure of water by promoting the tetrahedral arrangement of the water molecules.

Unlike the same quantities for salts in aqueous solution, the apparent molal expansibilities of the salts in glycol and methanol are negative and increase with the concentration of salt, thereby agreeing qualitatively with the predictions of the interionic attraction theory and the effective-pressure hypothesis. A comparison of the behavior of the salts in water on the one hand and in glycol and methanol on the other indicates that the structural changes in water do play a predominant rôle in determining the thermal expansions of aqueous solutions.

- (927) Crystallographic studies in the vivianite group. Tom. F. W. Barth. *Amer. Mineral.*, vol. 22, 325-341 (1937).

The geometrical elements of a crystal can be more accurately determined with an X-ray goniometer than is usually possible with a reflection goniometer. This is, of course, especially true for crystals with few or poorly developed faces. Several members of the vivianite group are encountered in such imperfect crystals that no determination of the crystallographic constants had been attempted. For other members the constants were known only approximately.

New X-ray measurements as well as reflection goniometer measurements on this series of minerals have been conducted, and the crystallographic constants of the several members have been established.

A survey has been made of the optical properties of minerals and artificial products belonging to the vivianite group. The mineral names *hautefeuilleite* and *caberite* have been discarded. They were supposed to stand for calcium-bearing *bobierite* and nickel-bearing *annabergite* respectively. But it has been demonstrated that in their optical properties, so far as the determinations go, they do not differ from those of the end members and that, thus far, no compelling evidence has been produced proving the existence of any such mixed crystals either in nature or among artificial products.

- (928) Leucite and pseudoleucite. Norman L. Bowen and R. B. Ellestad. *Amer. Mineral.*, vol. 22, 409-415 (1937).

Some of the lavas of Central Africa have rims of pseudoleucite surrounding leucite crystals, and since it has been considered that pseudoleucite forms from a soda-rich



leucite, the lavas and their leucite crystals have been examined chemically and microscopically in order to determine whether that hypothesis finds any support in these rocks.

It is found that the leucite crystals have but a small amount of  $\text{Na}_2\text{O}$ . Moreover, in related hypabyssal rocks containing leucite as a groundmass mineral—a most favorable case for the formation of soda-rich leucite, if such a mineral exists—it is found that the leucite again has but a moderate content of  $\text{Na}_2\text{O}$ .

The formation of pseudoleucite is then explained in the light of the equilibrium diagram of the system  $\text{NaAlSiO}_4\text{--KAlSiO}_4\text{--SiO}_2$ , with its "pseudoleucite reaction point."

(929) Silicate-water systems: The "osmotic pressure" of silicate melts. Roy W. Goranson. *Amer. Mineral.*, vol. 22, 485-490 (1937).

Previous papers have dealt with experimental determinations of the solubility of water in various silicate melts where the two phases water and silicate solution had been subjected to the same confining pressure. In this paper the solubility relations are evaluated for the case wherein the confining pressure is not the same on the two phases.

The necessary mathematical expressions are derived for this case, which is related to the phenomenon known as "osmotic pressure." The data necessary for evaluating these expressions were obtained from the above experimentally determined solubility relations together with unpublished data on the  $p$ - $v$ - $T$  relations of water at high temperatures and pressures and the heterogeneous equilibrium relations of silicate-water systems.

The "osmotic pressure," expressed as kilobars, is given as a function of water concentration in the silicate (albite) melt for  $1000^\circ\text{C}$ . and three different silicate-melt pressures, namely, 4, 3, and 2 kilobars.

The concentration of water in silicate solutions, when the confining pressure on the water is less than that on the silicate solution, is markedly less than if the same confining pressure acted on both phases. This fact may have important consequences in volcanism and may be the factor determining the rarity of rock glasses with any considerable amount of water in solution.

(930) Sulphate incrustations in the Copper Queen Mine, Bisbee, Arizona. H. E. Merwin and E. Posnjak. *Amer. Mineral.*, vol. 22, 567-571 (1937).

Four ferric sulphates, two ferric-ferrous sulphates, and a cupric sulphate are described with respect to temperature, progressive oxidation, acidity, and evaporation. A chart shows the zonal arrangement of the minerals, and a diagram of the system  $\text{Fe}_2\text{O}_3\text{--SO}_3\text{--H}_2\text{O}$  between  $30^\circ$  and  $40^\circ$  assists in explaining the zoning. A sliding diaphragm for testing the orientation of immersed grains is mentioned.

(931) The space-group and unit cell of sylvanite. George Tunell and C. J. Ksanda. *Amer. Mineral.*, vol. 22, 728-730 (1937).

Faceted crystals of sylvanite from Cripple Creek, Colorado (kindly furnished by Professor Charles Palache, of Harvard University), and from Săcărâmbu (Nagy-Ág), Transilvania (kindly supplied by Dr. W. F. Foshag, of the U. S. National Museum), were investigated by means of the Weissenberg X-ray goniometer. The dimensions of the unit cell were found to be  $a_0 = 8.94\text{ Å}$ ,  $b_0 = 4.48\text{ Å}$ ,  $c_0 = 14.59\text{ Å}$ , all  $\pm 0.02\text{ Å}$ ;  $\beta = 145^\circ 26' \pm 20'$ . The missing spectra show that the space-group is either  $Pc - C_s^2$  or  $P2/c - C_{2h}^4$ , and the crystal habit indicates that the latter is more probable. The unit cell contains two "molecules" of  $\text{AuAgTe}_4$ .



- (932) The relation between chemical composition and physical properties in the garnet group. Michael Fleischer. *Amer. Mineral.*, vol. 22, 751-759 (1937).

Examination of the garnet analyses published since 1915 has verified the direct relationship between chemical composition and physical properties found by W. E. Ford to exist in the garnet group. The refractive indices, specific gravities, and sizes of unit cells have been calculated for the different garnet molecules. The determination of the chemical composition of a garnet from its physical properties has been discussed briefly and some of the limitations of the method pointed out.

- (933) Accurate orientation of thin sections. Earl Ingerson. *Amer. Mineral.*, vol. 22, 760-772 (1937).

Since the methods of fabric analysis are being used more and more in this country, accurate orientation and uniform marking of thin sections are becoming increasingly important. In this paper is described an apparatus that can be used for the following: (1) to orient a hand specimen for laboratory study; (2) to measure the orientation of a plane surface other than the one marked; (3) to measure the direction and angle of pitch of a lineation; (4) to mark a plane (of a thin section) in a given position; (5) to measure the orientation of an *s*-plane or other plane that does not form a flat surface on the specimen.

The apparatus consists essentially of two parts: (1) a small table, equipped with a universal joint, for holding the specimen, and (2) a measuring device with a vertical and a horizontal circle on which dips and strikes, respectively, are read. Measurements can be made with it more accurately than similar measurements can ordinarily be made in the field.

A suggested system for marking thin-section blocks (hand specimens) and completed oriented sections is outlined and illustrated by photographs and diagrams.

- (934) Construction and properties of the manganin resistance pressure gauge. L. H. Adams, R. W. Goranson, and R. E. Gibson. *Rev. Sci. Instr.*, vol. 8, 230-235 (1937).

The measurement of pressure is an essential part of all research on the behavior of properties of materials exposed to very high pressures. The most important type of pressure-measuring instrument depends upon the variation of resistance with pressure. The manganin resistance pressure gauge has gradually been developed into an instrument of high precision. It is now the only type of pressure gauge in common use for the accurate measurement of pressures much above 500 bars.

In this paper a number of observations on the construction and properties of the manganin resistance pressure gauge are recorded. It has been shown that the pressure coefficient of a coil of wire depends on the size and construction of the coil as well as upon the composition of the wire. The linearity of the pressure-resistance relation also depends on the size and type of coil.

The effect of winding, of heat treating, and of pressure seasoning on the resistance and pressure coefficient of various coils has been determined and measurements have been made on the effect of temperature on the pressure coefficient of manganin.

Convenient equations applicable to the "fixed bridge" method for measuring small resistance changes are presented.

- (935) Mixing device for thermochemical calorimeters. Walter P. White and H. S. Roberts. *Jour. Amer. Chem. Soc.*, vol. 59, 1254-1256 (1937).

A device for liberating a powder into a solution in a thermochemical calorimeter is arranged to be immersed in the solution until thermal equilibrium is attained. The powder is then liberated by pulling a wire.

- (936) The chemical application of the Raman effect. James H. Hibben. Jour. Wash. Acad. Sci., vol. 27, 269-299 (1937). (Address of the retiring president of the Chemical Society of Washington.)

This presentation outlines the application of Raman spectra to chemical and physical problems. The theory of the Raman effect, the experimental technique employed in its use, and its utilization in the delineation of molecular structure are treated in some detail. The Raman shifts of nearly every type of organic and inorganic compound are described and the characteristic frequencies of particular types of linkage such as ethylenic, acetylenic, carbonyl, sulphydril, etc., are indicated, together with the observed modifications of such characteristic frequencies as a function of molecular constitution.

It is shown that this spectroscopic method of approach has materially aided in the determination of molecular structure in both organic and inorganic chemistry, particularly in those cases where no other method will yield satisfactory results. The accepted constitution of water, aqueous solutions, nitric, sulfuric, and phosphoric acids, various inorganic liquids, gases, and crystals, for example, has been verified in many cases and in others found to be in error. The interaction of solute and solvent, of organic and inorganic complexes is demonstrable by the Raman-effect method. In addition to providing a more accurate picture of the arrangement of the atoms in the molecule, it is shown that this method provides information concerning valence angles, forces between atoms, frequency and amplitude of atomic vibration, energy levels, specific heats, and other physical properties.

- (937) The pneumatolytic and hydrothermal alteration and synthesis of silicates. George W. Morey and Earl Ingerson. Econ. Geol., vol. 32, 607-761 (1937).

This paper consists of (1) a theoretical discussion and (2) an annotated bibliography.

The theoretical discussion considers general principles underlying pneumatolytic and hydrothermal processes, with application to the experimental results available in the literature. In addition, the experimental methods and apparatus are considered.

The bibliography contains detailed abstracts of all papers dealing with the pneumatolytic and hydrothermal alteration or synthesis of silicate minerals. There are also included several papers dealing with solubility and transport of silica, and a few that are devoted entirely to apparatus.

At the end of the paper are two indexes: a complete mineral index in which is indicated the temperature range that has been reported for each mineral, and an author index.

- (938) Volcanoes and human geography. E. G. Zies. Proc. Second General Assembly Pan American Institute of Geography and History, 1935, pp. 328-336 (Washington, 1937).

Human geography has been defined by Jean Brunhes as the study of the relations of human activity and the phenomena of physical geography. The volcanic areas Guatemala, El Salvador, and Java are excellent illustrations of this relationship. In spite of the devastation occasionally wrought by the various manifestations of volcanic activity, these unusually fertile regions are sustaining a large population. This is particularly true of Java, where the world has a fine opportunity to observe a carefully planned and scientifically controlled large-scale experiment in geographical adaptation.

A detailed study of volcanic areas located in equable climatic zones will show how the results of scientific endeavor can be joined by the coordinating thread of human geography to promote human welfare.

- (939) Tuffs and other volcanic deposits of Katmai and Yellowstone Park. C. N. Fenner. Trans. Amer. Geophys. Union, 18th Annual Meeting, pp. 236-239, Nat. Res. Council, Washington, D. C. (1937).

Certain significant features of the elastic deposits of the two regions are discussed.

The great rhyolitic tuff deposit of the Valley of Ten Thousand Smokes was produced by a form of eruption that was different in some respects from anything that had previously been recognized. It may be termed the Katmaian type of eruption. The features of this deposit are briefly described, and special attention is given to the firm consolidation of the fragmental material. This has been found to be due chiefly to the action of self-evolved pneumatolytic gases shortly after emplacement.

In Yellowstone Park, deposits with similar features have been found, which are probably of similar origin. Other elastic rhyolites of Yellowstone are due to somewhat different action, but likewise show solvent and devitrifying effects accomplished by energetic pneumatolysis.

Another type of elastic volcanics in Yellowstone Park is found in the great beds of basic material of an earlier period, made up largely of boulders. The attitude of the beds is nearly horizontal. The method by which sheets of bouldery volcanic material are widely spread, instead of being locally accumulated in conical piles, is discussed in the light of observations on certain forms of volcanic action made in various regions within recent years.

- (940) Silicate science. George W. Morey. Jour. Amer. Ceram. Soc., vol. 20, 283-287 (1937).

An address delivered at the General Session of the Thirty-ninth Annual Meeting of the American Ceramic Society. In it an attempt is made to correlate by means of the changing proportions of silica in a crystallizing rock magma the various branches of science and technology which are concerned with the properties of silica. Such a discussion serves to bring out both similarities and differences between the processes taking place in nature and those characteristic of the many branches of technology dependent on the properties of silicates.

- (941) The compressions of solutions of certain salts in water, glycol and methanol. R. E. Gibson. Jour. Amer. Chem. Soc., vol. 59, 1521-1528 (1937).

In the course of a survey of the effects of pressure on chemical systems containing two components, measurements of the compression to 1000 bars of a number of aqueous salt solutions have been published (Papers Nos. 839, 843, 870, and 883). It was found that these measurements for a single pressure change could readily be used to compute the compressibilities of the solutions at all pressures. A comparison of the specific effects of equivalent amounts of salts on the compressibility of water showed that small or highly charged ions such as lithium, magnesium, or beryllium do not lower the compressibility of water as much as would be expected. Furthermore it was found that no direct relationship between the compressibility and the thermal expansibility seemed to hold for aqueous solutions. To illuminate these questions and to extend the experimental search for those properties of the pure components which are of significance in the prediction of the behavior of a solution under changes of pressure and temperature, the compressions of a number of salts in solvents other than water, viz. glycol and methanol, were measured. A new pressure apparatus consisting of a bomb furnished with two glass windows was built so that phenomena under pressures up to 1500 atmospheres could be observed visually. This together with the use of silica glass piezometers materially improved the precision of the measurements.

The nonaqueous solutions of the salts studied behaved under pressure in many ways like the aqueous solutions, but they differed in three significant respects. The



anomalous behavior of lithium salts already noticed was not observed in glycol and methanol solutions. There was a marked correlation between the compressibility and the thermal expansibility of glycol in different salt solutions. Up to high concentrations of salt, equivalent solutions in methanol of four salts whose aqueous solutions differed markedly all had the same effective pressures. The partial volumes of the salts in different solvents and at different pressures have been examined and certain general conclusions concerning the effect of the solvent and the pressure on the change of solubility with pressure were drawn.

- (942) Chemical applications of the Raman effect: I. Polymerization. James H. Hibben. *Jour. Chem. Physics*, vol. 5, 706-710 (1937).

The Raman spectra of methyl methacrylate as the monomer and in different stages of polymerization were investigated in order to obtain some information concerning the mechanism of polymerization and the molecular constitution of an amorphous compound having the properties of a glass. In addition, two other compounds, ethyl maleate and ethyl fumarate, were studied and their spectra compared with those obtained from the methyl methacrylates. The results indicate noticeable constitutional changes on polymerization and the existence of a coupling mechanism by direct addition on the ethylenic double-bond.

This is shown by the disappearance of the C=C shift at  $\Delta\tilde{\nu}$  1638 and the  $\text{=C}<\begin{smallmatrix} \text{H} \\ \text{H} \end{smallmatrix}$  frequency at  $\Delta\tilde{\nu}$  3100. These results permit an explanation of the continuing structure present throughout the solid and the mechanism by which this structure comes into existence. This is an essential feature in the formation of glasslike compounds. These experiments also indicate that when the monomer is less than 10 per cent polymerized—or when only a small portion of the total number of molecules present are bound together in an open weblike structure throughout the liquid—the physical properties of the liquid may be enormously altered.

- (943) Chemical applications of the Raman effect: II. Common ion effect. James H. Hibben. *Jour. Chem. Physics*, vol. 5, 710-712 (1937).

The influence of adding common ions to solutions of compounds whose components are bound by a linkage, homopolar in nature, was investigated by means of the Raman effect. This represents possibly the only practical method extant for investigating solutions of this type. While the results are more or less in agreement with what may be expected from the classical theory of the common ion effect, there has heretofore been no extensive means available which would permit such a correlation. In the case of zinc chloride, for example, it is shown that the Raman frequency occurring at 275 wave numbers is due to the symmetrical  $\text{Zn}\longleftrightarrow\text{Cl}$  oscillation. The intensity of this shift in a  $\frac{1}{2}$  molal zinc chloride solution is decreased by diluting the solution to  $\frac{1}{4}$  molal. This intensity diminution, however, is much greater than the amount of dilution. This indicates a greatly increased degree of ionization of the zinc chloride in the more dilute solutions. If a salt, having a common chloride ion, is added to the  $\frac{1}{4}$  molal solution, the ionization is repressed to such a degree that the concentration of un-ionized zinc chloride is greater than it is in the  $\frac{1}{2}$  molal zinc chloride solution containing no common ion. The amount of ionization repression depends on the concentration of the chloride ion. If another zinc compound such as zinc sulfate is added, the common ion effect is much less marked. This is attributed to the homopolar binding of the zinc atoms and consequent lack of actual common zinc ions in solution.



- (944) Core samples of the ocean bottom. Charles Snowden Piggot. *Smithsonian Rept.* for 1936, pp. 207-216 (1937).

This article includes the material of Laboratory Paper No. 902 (Apparatus to secure core samples from the ocean bottom, *Bull. Geol. Soc. Amer.*, vol. 47, 675-684 [1936]) and in addition a report of soundings made across the North Atlantic in 1936, treated in somewhat less technical phraseology. The article also considers briefly the reasons for and significance of these investigations and some of the results expected from them.

- (945) Equilibrium relations and factors influencing their determination in the system,  $K_2SiO_3-SiO_2$ . F. C. Kracek, N. L. Bowen, and G. W. Morey. *Jour. Phys. Chem.* (in press).

In a former paper from this Laboratory (Paper No. 688), liquidus relations for this system were presented, which were characterized by an unexpectedly complex form of the melting curve for the compound  $K_2Si_2O_5$ . The compositions in this region of the system are exceedingly hygroscopic; the absorbed moisture facilitates the growth of microscopically large crystals, which upon dissolution produce marked inhomogeneity in the preparations, and lead to the determination of false equilibria. In this paper is presented a new study of the liquidus relations, and of the effect of the absorbed moisture upon their determination. The liquidus curve for  $K_2Si_2O_5$  is found to be of the normal type, rising to a maximum at the melting point of the compound, and descending smoothly on either side to the eutectics with  $K_2SiO_3$  and  $K_2Si_4O_9$  respectively. A study has also been made of inversions in the crystalline compounds  $K_2SiO_3$ ,  $K_2Si_2O_5$ , and  $K_2Si_4O_9$ .

- (946) Annual Report for 1936-1937.

## DIVISION OF HISTORICAL RESEARCH <sup>1</sup>

A. V. KIDDER, CHAIRMAN

The Division of Historical Research comprises three Sections. The Section of Aboriginal American History concerns itself with studies relating to the rise of native civilization in the New World, its two principal fields being the Maya area in Mexico and Central America and the Pueblo area of southwestern United States. The Section of Post-Columbian American History conducts research upon the growth of Western European institutions in the Americas. The Section of the History of Science strives to bring together and to make available for interpretation the at present widely scattered and uncoordinated data which bear upon the acquirement and transmission of ordered knowledge.

### SECTION OF ABORIGINAL AMERICAN HISTORY

The year's investigations have yielded an unusual amount of valuable material. Of outstanding archaeological importance were data upon ball courts and upon the great Hieroglyphic Stairway gathered by Mr. Strömmsvik and Dr. Morley at Copan; a remarkable fresco and hieroglyphic inscription were found by Mr. A. L. Smith at Uaxactun; from the Chairman's excavations near Guatemala City came a large collection of pottery, jades, and other mortuary objects from an area hitherto little known. Work upon the living Maya under direction of Dr. Redfield resulted in the rescuing, by Sr. Villa, of much knowledge regarding the fast-fading native culture of the Indians of eastern Yucatan. The historical research was rewarded by discovery of unsuspected documentary riches in the archives of Guatemala. Results of all Divisional activities are summarized in the subjoined reports.

#### UAXACTUN—A. L. SMITH

After twelve seasons of intensive investigation, the Division's activities at Uaxactun were brought to a close on May 15, 1937, and the camp and permanent equipment were turned over to the Government of Guatemala. Originally selected by Dr. Morley for excavation because, on the basis of its dated monuments, it was both the oldest and the longest inhabited of Old Empire Maya cities, Uaxactun has paid consistently rich scientific dividends. Work there is now being terminated not because the site is even approaching exhaustion, but in order to allow Mr. Smith and his associates to bring up to date their studies of, and publications upon, the large collections and the abundant data already recovered. And it seems probable that when these tasks have been accomplished problems will have been formulated which will call for comparative research at other sites rather than for further work at Uaxactun.

Discovered by Morley in 1916, Uaxactun was revisited by him for epigraphic study in 1921 and 1922. In 1923 its geographic position was ascertained by W. A. Love, of the Institution's Department of Terrestrial Magne-

<sup>1</sup> Address: Carnegie Institution of Washington, 16th and P Streets, N. W., Washington, District of Columbia.

tism, and in 1924 F. Blom and W. M. Amsden mapped the site in preparation for the opening of excavations by O. G. Ricketson in 1926. The first five seasons were devoted to stratigraphic study of the early pre-stela deposits in Group E and to clearing various surrounding structures, the most important of which was the excellently preserved Pyramid E-VII Sub.<sup>1</sup> During these years, all monuments at Uaxactun were carefully examined for sub-stela caches, and squeezes were made of the best-preserved monuments.

In 1931 activities were shifted to Group A, where, during the past seven years, the major part of the work has been concentrated on Structure A-V, a large and long-occupied "palace type" complex which contained invaluable stratigraphies, both ceramic and architectural. Also wholly or partially excavated were Structures A-I, A-II, A-III, A-XV, and A-XVIII, and a most important rubbish heap rich in pottery was discovered. A reservoir west of the causeway connecting Groups A and B was examined, as well as several structures in Group B, the most interesting of which were a ball court and Structure B-XIII. Testing was done in Groups C, D, and F, and in 1935 a new group, H, was discovered south of Group E.

During 1937 the investigation of Structure A-V was completed by determination of certain hitherto unascertained building sequences, and by collection of several pottery samples to check against those of previous years. Structure A-XVIII was further examined, its substructure being found to consist of three terraces. A trench into the south side of the building through the central doorway revealed, in the terrace in front of the doorway, an incised pottery vase surrounded by four eccentric flints and three eccentric obsidians, and containing two jade beads, two jade ear plugs, and a jade idol 10 inches high, weighing 11.5 pounds.

Structure A-II was excavated because it is associated with the two latest dated monuments at Uaxactun—Stela 12 (10.3.0.0.0) and Stela 13 (10.0.0.0.0). It proved to be the latest type of building so far uncovered at this site. What little of its superstructure remained showed that on its east side it had five doorways separated by masonry piers, the only example of this arrangement found at Uaxactun. The breadth of the temple's single room and the paucity of fallen masonry indicated that it had been roofed with beams and mortar or thatch, probably the latter.

The excavation of Structure B-XIII, begun in 1935, was sufficiently advanced to prove that it had undergone several reconstructions, all of Period I masonry, and that some of its rooms once supported beam-and-mortar roofs. On the back wall of one of these rooms was a well-preserved fresco depicting a small unvaulted building, within, in front of, and behind which are many elaborately garbed figures apparently engaged in a ceremonial. Below the main part of the fresco is an alignment of 72 day signs in consecutive order starting with 12 Imix and ending with 5 Eb. Many of these glyphs present hitherto unknown variants of recognized forms. Sr. Antonio Tejeda, staff artist in Guatemala City, made a special trip to Uaxactun to copy the fresco.

Structure B-XII, a two-room building north of B-XIII, was of interest in that, although it is of Period I, its vault approaches the later type which

<sup>1</sup> For further information regarding the various structures mentioned in this report, see Year Books Nos. 26-35.

utilizes well-shaped bevel-faced stones rather than flat uncut stones. This would suggest that vault construction was beginning to be refined before veneer stones were employed in the walls of buildings.

Other work in Group B was an unsuccessful search for markers in, and for a possible earlier structure below, the ball court excavated in 1936. Investigation of the causeway connecting Groups A and B revealed an earlier causeway below the one studied in 1936. It differed from the latter in its lack of a parapet and in that its sides rose in two terraces. Ceramic evidence connects the early causeway with Period I construction.

Structure E-X was further examined. The three rooms of this well-preserved building were cleared in 1927. During the past season it was discovered that these three units were originally a single long room. On the roof was uncovered a roof comb, a single long, narrow chamber, its back wall resting on the back wall, its front wall on the capstones, of the room below. This produced a frontal terrace. Access to the roof comb was gained by two narrow elbow-shaped passages through the capstones of the lower vault.

#### COPAN—G. STRÓMSVIK<sup>1</sup>

The third season of cooperative work by the Government of Honduras and Carnegie Institution of Washington at Copan opened December 1, 1936, to take advantage of the full six months of dry winter weather. Activities of the year were: further attempts to protect the ruins from destruction by the Copan River; study and repair of the Hieroglyphic Stairway; and completion of study and repair of Temple 22. As in former years, the Government has defrayed all costs of labor and of the transportation of supplies. Dr. Jesus M. Rodriguez, Minister of Public Education, under whose auspices the project is carried on, visited the site several times during the season for conferences with Mr. Strómsvik, Dr. Morley, and the Chairman. Dr. Rodriguez' unremitting interest in and support of the work have not only been of great practical value but have also permitted personal contacts highly prized by the Division's staff. Thanks are likewise due to Colonel Jose A. Rivera, government representative at Copan.

In the struggle with the river, the dam which had been built in 1936 and later washed out by the summer floods was replaced by a longer dam reinforced by several hundred piles, and the diversion canal was widened and deepened. Signs of a flank attack by the rising waters of early summer were becoming evident when Mr. Strómsvik left Copan in June, and it is possible that complete diversion of the river may never be feasible. If so, protection by riprapping will have to be afforded the base of the Acropolis. It is imperative that this important structure be saved.

Repair of the magnificent Hieroglyphic Stairway was begun. Dr. Morley, who was at Copan for a month in the late winter studying new epigraphic material, and assembling and arranging the fallen sections of the stairway preparatory to their replacement, reports that about sixty-two steps constituted the original flight. Only the bottom fifteen were in situ. Fifteen others, however, had slid downward en bloc. These, excavated in the 1890's by the

<sup>1</sup> For reports upon the investigations of 1935 and 1936, see Year Books Nos. 34, 35.



Peabody Museum of Harvard University and laid out in the plaza in their proper order, were replaced during the past season in the position which it is almost certain they had formerly occupied.<sup>1</sup> Rehabilitation and study of the Hieroglyphic Stairway being incomplete, its description is reserved for a future report.

Discovery of a ball court between Structures 9 and 10 near the Hieroglyphic Stairway (tentatively dated by Dr. Morley at 9.17.4.0.0) was perhaps the outstanding event of the season.<sup>2</sup> It overlies two earlier ball courts, the middle one possessing three finely carved, circular stone "markers," the oldest showing traces of having had circular plaster "markers" decorated with paint.

Mr. Trik completed the excavation and repair of Temple 22, which he began in 1936. Last season, attention was devoted to the clearing of the mound and to reassembly of the interior sculpture. It was found that enough of the building was standing to justify continuation of repair, and to permit thorough study of one of the most important and most complete structures in Copan.

Work was resumed by clearing the north room of debris. The sculptured stones originally over the interior doorway were found piled in the room, where they had been placed by some earlier excavator and subsequently covered by falling walls. These stones completed the sculptured decoration of the room.

The west transverse room yielded information on vault construction. There a wooden lintel over a niche had rotted, allowing a large section of the vault to fall en bloc with the stones still in position, showing a fine construction of long, carefully fitted, corbeling stones. Exceptionally long-tenoned vault stones were found throughout the building, about 80 cm. being an average, but some reaching a length of 1.30 m. The weakness of the vault was apparently in the lack of a strong binder rather than in the cutting and setting of the stones.

The ground plan of the temple was found to be quite different from any of the published plans in that the east and west rooms are not symmetrical, while the north room does not have the two narrow wings shown in all earlier plans. It was evident that the temple had never before been completely cleared, as niches in the north and west rooms, a passageway in the east room, and a dais in the west room had not been discovered.

Investigation of the base courses of the walls showed that its original design had been changed during construction and gave clear indication of the method followed in laying out the rooms when the building was begun. This was done by setting single courses of stones at about floor level, thus providing lines to be followed as the walls were erected. Where changes in plan occurred, such courses were covered by the new walls.

The platform on which the temple stands was cleared and repaired, and the stairway leading up to the platform was reset. This consists of eight steps

<sup>1</sup> Dr. Tozzer kindly supplied copies of original notes and photographs from the files of Peabody Museum, without which this undertaking could not have been carried out.

<sup>2</sup> Other new dates deciphered by Dr. Morley are: the step of Temple 11 (9.16.15.0.0) and Altar W' (9.18.0.0.0).

about 8 m. long and contains some of the largest stones used in Copan. Several are over 2 m. long and weigh approximately a ton and a half.

Evidence that the temple had been used as living quarters after its abandonment as a ceremonial building was found in the form of occupational refuse. During the clearing of the rooms and terrace floor, numerous artifacts and pieces of sculptured decoration were encountered. Among these was a beautifully chipped obsidian ceremonial blade measuring 33 cm. in length. The outstanding piece of sculpture was an unusually well-preserved head of the "Singing Girl" type, from the west side of the platform. It, with other similar pieces, formed a part of the façade decoration.

A study of the scattered sculpture was begun, particularly of such parts as could definitely be assigned to some part of the building. As no part of the upper zone was standing, this examination was limited to the elaborate masks on the four corners of the temple and to the large serpent mask forming the entrance. Unallocated stones were sorted and piled where they will be available for further study.

In connection with reconstruction of the Hieroglyphic Stairway, the summit of Mound 26, up which the stairway led, was investigated in order to find the level of the temple platform as one check on the number of steps in the stairway. No indications of a building were evident until removal of surface debris revealed large, scattered fragments of a very thick, hard floor. By fitting these together, like sherds of pottery, most of the outline of a chamber was reconstructed. Its limits were clearly indicated by the turned-up edges of the flooring where it had abutted the walls, and the doorway was located by pieces which projected beyond the line of the front wall. Forty-four beautifully carved stones were found. These had formed part of a four-course frieze of full-figure glyphs, probably across the medial wall, two courses apparently in the wall and two in the vault. Two stones of the lower course had cord-holders, indicating that the band had been carried on wooden beams over an interior doorway. Some seventy similar stones from the slopes of Mound 26 are now in Peabody Museum and in Tegucigalpa. It is probable that they are part of the same frieze and that the assemblage can be completed. If so, it will constitute the longest inscription now known in the very rare full-figure hieroglyphs.

A small amount of digging was done on the southwest corner of the mound in order to locate the terrace walls. Four of the upper terraces were found and recorded and the excavations refilled as protection from further destruction.

#### CHICHEN ITZA—S. G. MORLEY

Mr. Karl Ruppert spent six months at Chichen Itza gathering data for an evaluation of Nahua influence upon the architecture of that city, and for a report on such structures as have, wholly or in part, been excavated and for which there is no published record. A survey and analysis of the Nahua structures presupposes a knowledge of the Maya buildings at the site. This survey is to be purely local and such facts as may be determined will apply only to Chichen Itza and here, of course, will be true only as far as present excavations have been conducted and surface examinations extended. Certain

architectural features such as serpent columns have come to be identified as definitely Nahua; thus buildings in which these are utilized in key constructions must be considered as of the late period. Late concepts appear in early structures only where they have been added as roof ornaments or other superficial decorations, never as fundamental elements of construction.

The survey has included the examination of eight ball courts. Seven, in which stone rings have not been found, have benches one-third or less the length of the largest court. All are apparently of the late period and show great differences in slope of face and top of bench. The main walls, however, seem to rise vertically. Because of the extreme variation of the courts, it is evident that the game could not have been standardized; and the possibility of its having been played in the single enormously large court may, in Mr. Ruppert's opinion, perhaps even be questioned.

The plans of structures in the two periods show little in common. The two-chambered temple resting on a lofty pyramid and now encased within the Castillo is, if correctly interpreted, the only example of such a structure in Maya times. Buildings of the palace type are not associated with the Nahua. The shrine room, which is not represented here in the Maya period but is found in their cities to the south, was developed and elaborated by the late people of Chichen Itza. Arrangements of colonnades of one to four vaults in depth, colonnades and temples, and cloisters appear that do not have counterparts in early structures.

Carved stone was the medium used for building ornamentation during both periods, and practically all motifs are carried from early to late times. Façades in both periods, except for two- and three-member moldings, may be plain. If ornamented, those of the Maya showed a tendency toward over-all decoration, while the Nahua more consistently simplified the treatment by the use of alternate plain and sculptured panels. Realistic bas-relief was not attempted by the Maya.

Differences are noted in the manner of cutting, dressing, and laying stones, and in late times stones of the vault were highly specialized. The floor level of the inner chamber is placed a step up from that of the outer chamber—a common Maya feature which is not seen in unquestioned Nahua structures. Numerous minor but evidently none the less significant differences in construction, developed or brought in by the Nahua, become apparent as the material is analyzed.

Dr. Morris Steggerda, accompanied by Dr. T. J. Hill, of the Institute of Pathology of Western Reserve University, reached Chichen Itza early in February, the former remaining for two months, the latter for a month. Dr. Steggerda continued his study of the local Maya, whose anthropometry, ethnology, sociology, psychology, genetics, and economic life he has been investigating for the past six years (see this report, pp. 150–151). Dr. Hill examined the dentition and saliva of the Maya, taking specimens of the latter for further study in the United States.

Mr. Ralph Roys made his headquarters at Chichen Itza from the middle of February to the end of March. He identified a number of points on the frontier between the ancient provinces of the Cupules and the Cocoms, men-



tioned in the Ebtun Papers, of which his annotated translation is being prepared for press. His report will be found on pp. 157-158.

Dr. S. A. Barrett, Director of the Public Museum of Milwaukee, accompanied by Mr. George Peter, of the museum staff, spent the month of April at Chichen Itza collecting data—photographs, paintings, drawings, and descriptions—for the construction of six groups at the museum illustrating various phases of ancient life at Chichen Itza.

Dr. Josselyn Van Tyne, of the Museums of the University of Michigan, was at Chichen Itza during July and August collecting birds. Last year he made a similar collection during the dry season (March and April) and with the specimens secured this year it is possible to describe the avifauna of the region throughout the year.

On the return trip from Copan to Chichen Itza early in March, Dr. Morley visited the canal just north of Puerto Barrios, Guatemala, where the Leyden Plate was found about three-quarters of a century ago, and also flew over the ruins of Yaxha, Uaxactun, Tikal, and Tayasal, landing at Flores, capital of the Department of Peten. He remained at Chichen until August, dividing his time between administrative work and reading proof of his monograph upon the inscriptions of the Department of Peten, Guatemala.

#### THE ARCHITECTURAL SURVEY—H. E. D. POLLOCK

Dr. Pollock's activities in 1937 differed from those of earlier years<sup>1</sup> in that instead of collecting definitive data on the architectural remains of relatively limited areas, he made rapid reconnaissance of an extensive territory. At the same time, he was able to visit several sites under excavation and to observe others that had witnessed a certain amount of digging in past years.

The first part of the season was devoted to the Guatemalan highlands, a region rapidly becoming more accessible to travel but which as yet is archaeologically little understood. Prior to this the lowland ruins of Quirigua and Copan were visited, as well as San Agustin Acasaguastlan and the little-known ruins of Papalguapa and Asuncion Mita.

The next group of remains investigated was that centering about the town of Santa Lucia Cozumalguapa, on the Pacific slope of the cordillera. The sites of El Baul, El Castillo, Pantaleon, Bilbao, Aguna, Los Tarros, Palo Verde, San Andres Osuna, and El Portal, the last near Antigua Guatemala, were seen during this trip.

The final and most extensive phase of the highland survey included examination of an unnamed mound group between Kilometers 65 and 66 on the road from Guatemala City to Teepan, and the well-known ruins of Iximche. A stop in Chichicastenango allowed observation of the famous Rossbach collection. On succeeding days the sites of Utatlan, Chiche, Joyabaj, Zacualpa, Comitansillo, San Pablo Jocopilas, San Pedro Jocopilas, Saculeu, and three sites in the vicinity of Aguacatan were visited. Lastly, Dr. Pollock with Dr. Kidder inspected the Lake Atitlan ruins of Chuitinamit, Pachiuak, Chukumuk, Xikomuk, and Pavocol.

<sup>1</sup> For previous reports of the Architectural Survey, see Year Books Nos. 30, 31, 34, 35.



The above trips necessitated frequent passage through Guatemala City, where it was possible to see the excavations being carried on at Kaminaljuyu and to study the collections in the Guatemala National Museum.

Dr. Pollock devoted the second part of the season to reconnaissance of ruins on the Pasion and Usumacintla Rivers in company with Messrs. Smith and Shook.

Starting from Uaxactun, where Dr. Pollock had opportunity to see the results of over ten years of intensive excavation, the combined party moved southward to the ruins of Tikal, where four days were spent. This visit resulted in the discovery of a previously unreported group of remains located about 1 km. north of the Great Plaza, two new sculptured stelæ (19 and 20), a sculptured altar (VIII), five plain stelæ, and six plain altars. According to Dr. Morley, Stelæ 19 and 20 record the dates 9.18.0.0.0 and 9.16.0.0.0, respectively, each date being declared as a Period Ending. Leaving Tikal the expedition continued southward, visiting Ixlu, Tayasal, and Chakantun, in the course of the journey to Subin Creek, a branch of the Pasion River.

The small ruin of Aguas Calientes was the first site reached on the Pasion. The following day the party visited an unreported site about 3 km. ESE. of the settlement of La Florida on the left bank of the river. The ruins were given the name El Caribe, from a nearby arroyo of that name. Two sculptured stelæ (1 and 2), a hieroglyphic step-stone, and a plain altar were here discovered. While the readings are as yet uncertain, Dr. Morley feels that Stelæ 1 and 2 probably were erected to commemorate the date 9.17.10.0.0. Next day a second new site, situated some 4 km. south of La Florida and given the name La Amelia, was examined. This yielded a sculptured stela and six step-stones, all carrying epigraphic texts that still await decipherment.

The little-known ruins of Altar de Sacrificios at the confluence of the Pasion and Salinas Rivers, which together form the Usumacintla, were next visited. Exploration here revealed five new sculptured stelæ (8 to 12), two new sculptured altars (2 and 3), five plain altars, and the fragments of two doubtful stelæ. While much of the hieroglyphic material on these monuments remains to be deciphered, it seems clear that Stela 12 records the Initial Series 9.4.10.0.0, a very early date for this region, and Stela 8 the Initial Series 9.9.15.0.0. It is also reasonably certain that Stelæ 9, 10, and 11 record Initial Series dates.

The party continued downstream to the ruins of Yaxchilan, El Chile, El Cayo, and Piedras Negras, at the latter site being most kindly entertained by the Pennsylvania University Museum expedition, now at work there. Lastly, four days were spent at Palenque.

The results of such rapid and far-flung reconnaissance will become most clearly evident in the course of future work. New problems are defined, old ones are clarified, a more intelligent, more efficient program is made possible. The Guatemalan highlands constitute a region of great archaeological complexity, in that they not only have witnessed a relatively long period of occupation but have been subjected, at certain times, to numerous outside influences and cross-currents of culture. Any considerable amount of excavation in an area so little understood should be preceded by wider and more thorough reconnaissance than that undertaken this year. It is

wholly probable that one or two seasons of careful work of this sort would go far toward determining cultural boundaries, and sub-areas delimited by these boundaries, with characteristic remains of each; and should also permit selection of strategic points for attack.

The Usumacintla region has long been known to abound in impressive archaeological remains. It is an area, however, that is extremely difficult of access and that, for some years to come, will probably be very expensive to explore. As in the highlands, further reconnaissance seems advisable, but even careful reconnaissance in the Usumacintla country is arduous and costly. A site of obvious importance is Altar de Sacrificios—El Pabellon at the junction of the Pasion and Salinas Rivers, streams that drain the eastern lowlands and the southern highlands respectively, and that almost surely were ancient highways of commerce. The site should thus have been a meeting place of cultural currents from the Guatemalan highlands, the Peten lowlands, and the Usumacintla region. Work at this site might not only yield indications of movements of culture and material of value for chronological cross-checking, but would greatly facilitate further exploration of the region, the confluence of the Lacantun and Usumacintla Rivers being a point of special promise.

#### GUATEMALA HIGHLANDS—A. V. KIDDER, J. D. JENNINGS

Kaminaljuyu, a great aggregation of mounds in the southwestern outskirts of Guatemala City, has long been known to archaeologists and has long been believed important because Gamio's excavations of 1925 had revealed the presence there of a presumably early culture; because of Lothrop's identification of sculptures indicating influence from the Maya Old Empire; and because, being situated athwart probable highland routes of migration and commerce, it might be expected to yield trade objects valuable for determining cultural and chronological relations between various Middle American civilizations. The Institution began work here in 1935 with excavations to check Gamio's findings. Much ceramic material from the early period was recovered.<sup>1</sup> In 1936 a mound on Finca La Esperanza was partially excavated;<sup>2</sup> it was completed during the past season and the frontal terrace of a second mound was investigated.

Mound I proved to consist of eight structures, built one over the other. The two innermost were rectangular, vertical-walled platforms, the first of masonry, the second of adobe; the next six were truncated pyramids, the first four of adobe, the last two of water-rounded tufas laid in adobe. The total height of the complex was about 6 m.

The top of each pyramid had been reached by a stairway, and the summit platform of each had supported a superstructure, presumably a small temple. The current temple had been razed at each successive enlargement of the mound; that surmounting the outermost pyramid either had never been erected or had completely disappeared through erosion. Only the stairway of the last adobe pyramid had escaped destruction; buried in its exact center, halfway up, was a boulder of crude jadeite weighing some 200 pounds.

<sup>1</sup> Year Book No. 34, p. 121.

<sup>2</sup> Year Book No. 35, pp. 130, 131.

Associated with Mound I were six tombs, two of which, covered by the frontal platforms of the last two structures, were excavated in 1936; the other four, lying below the mound, were cleared during the past season.

Of Mound II only the frontal platforms were excavated. Like those of Mound I, they covered tombs, two of which could be assigned to the two major building stages of the platform; the third was intrusive.

All nine tombs were rectangular pits, sunk from 1 to nearly 5 m. into subsoil. Some certainly, all probably, had been log-roofed. Each contained a principal skeleton lavishly adorned with jade, mosaic "mirrors," and shell ornaments, and accompanied by the skulls or complete skeletons of several other individuals, presumably slaves; much mortuary pottery was present, as well as remains of elaborate offerings of textiles and other perishable objects.

Interments and accretions to the mounds were apparently correlated, and definite connection between certain tombs and certain structures could be determined. Relative uniformity of funerary practice and close similarity between pottery from all graves indicates a short time-span for the entire series. The pottery evidences trade relations with northern Peten during the Tzacol period (middle to late Old Empire) and with Teotihuacan, Mexico.

At Kaminaljuyu three ceramic phases have so far been identified: Miraflores, early, possibly akin to the Mexican "Archaic"; Esperanza, the phase of the mounds and tombs, contemporaneous with the Maya Old Empire; Pamplona, crude, late, as yet unrelatable to any other group. Surface sherds from elsewhere on the site suggest presence of additional phases, and raise hope that it may eventually be possible to trace a long, continuous local evolution whose stages can be fitted into the larger scheme of Middle American cultural development.

#### CERAMIC TECHNOLOGY—ANNA O. SHEPARD

Of all archaeological materials, pottery is the most useful for tracing the development and spread of cultures, and for measuring the strength and identifying the source of external cultural influences. But its value for such purposes depends upon the certainty with which ceramic types can be recognized and defined, and upon the accuracy and uniformity of their description. Until very recently, however, pottery has been classified almost solely on the basis of its external characteristics—vessel form, color, decoration—features so subtly variable that their recording in terms sufficiently objective to be of service to other students is extremely difficult. Attempts have been made to use the more definite and tangible evidence offered by clays, tempering materials, and pigments; but success has hitherto been meager, because no archaeologist has had the highly specialized knowledge required for certain identification of the various ceramic ingredients.

When, therefore, Miss Shepard, a trained petrographer, began the study of ceramic technology, she entered a practically virgin field. Her work on ancient Pueblo pottery quickly demonstrated its value in permitting more accurate and more objective description of wares. She has also often been able to recognize, in pottery, mineral inclusions not found in local deposits



and, by identifying their source, has not only proved the vessels in question to be trade pieces, but has in many cases been able to determine their place of origin. This is obviously of the greatest importance to the archæologist.

Miss Shepard, through cooperation of the Laboratory of Anthropology at Santa Fe, has for several years taken part in the Institution's studies of Southwestern and Maya pottery. On January 1, 1936, she joined the Division staff on temporary appointment. She has continued her research upon the collections of E. H. Morris from the La Plata region of northwestern New Mexico, and upon those of J. E. Thompson from British Honduras. During the past winter, she spent six weeks in Guatemala studying, with R. E. Smith, the wares of Uaxactun. An unexpected result of Miss Shepard's Maya work has been the discovery that a large percentage of the pottery from British Honduras, from Uaxactun, and even from northern Yucatan contains tuff temper, although no deposits of this material are presumably to be found within long distances of the sites producing the vessels. The pottery nevertheless appears to be of local manufacture. This raises problems of the extent and direction of aboriginal trade in raw materials, whose solution will throw much light upon prehistoric conditions in the Maya area.

ETHNOLOGICAL AND SOCIOLOGICAL RESEARCH—R. REDFIELD, S. TAX,  
A. T. HANSEN, A. VILLA

Previous reports have described the two research enterprises carried on by the above four men.<sup>1</sup> One is a comparative study of four communities in Yucatan: the city of Merida, a town on the railroad, a peasant village, and a settlement of semi-independent, tribally organized Maya of east central Quintana Roo. The principal objective of this study is to trace changes in and disorganization of the integrated folk culture, composed partly of Indian and partly of Spanish elements, which grew up in the hinterland after the Conquest. Year Book No. 35 contains a summary of the accomplishments in the field during the previous season of Mr. Villa, to whom has fallen the task of studying the Quintana Roo Maya. The studies of the other three communities were completed before 1936, and a monograph on the peasant village, Chan Kom, has appeared. Mr. Villa's field work was finished in the winter of 1936-1937. As this brings to an end the collection of data required for the study as planned, no further reports on this project may be expected until the results appear in volumes now in preparation. These are three: a monograph on the city of Merida by Dr. Hansen; a monograph on the X-Cacal *cacicazgo* of east central Quintana Roo by Mr. Villa; and a summary and comparative volume on culture and civilization in Yucatan by Dr. Redfield.

During the latter part of Mr. Villa's residence in Tusik, a village of the X-Cacal group, he completed the collection of materials in such a way as to insure a point-for-point comparison of the Quintana Roo culture with that represented in Chan Kom, the peasant village. Anticipating a more considered statement, one may set down some of the more important contrasts

<sup>1</sup> Year Books Nos. 29-35.



between these two societies: (1) The techniques practiced, the familial institutions, and the folk beliefs and other ideologies of the two peoples are so similar as to be almost identical. (2) But the political organization, and such structure as exists outside of the family, is sharply different in the two societies. The government of Chan Kom is a part of the state and national governments, and functions to express the wish of the people to identify themselves further with "civilization and progress"; the Quintana Roo natives rule themselves and exclude the modern world through a theocratic-military hierarchy of chiefs. This difference reflects the contrast in essential social objective, the one progressive, the other intensely conservative. (3) The religious rituals present some notable points of contrast in (a) the emphasis in Quintana Roo upon group ceremonies, especially those affecting the entire subtribe; (b) the greater importance of Catholic ritual elements in Quintana Roo; (c) the persistence of pagan features in Quintana Roo which are extinct in Chan Kom; but on the other hand (d) the absence in Quintana Roo of a number of pagan elements which are still present in Chan Kom. This last situation presents a special problem calling for historical explanation. Related to it is the relatively smaller importance of the shaman-priest (H-men) in the more isolated and otherwise primitive community as compared with the corresponding situation in Chan Kom. The Quintana Roo people developed a paramount leader, sacrosanct, in the person of the functionary (Nohoch Tata) who maintains the tribal shrine and ritual. This is probably an adaptation of Christianity to primitive conditions, made in adjustment to the necessity for organizing the tribe against outside attack. Incidentally it may have brought about diminution in the authority of the more pagan H-men.

It should be reported that incidentally to his scientific work, Mr. Villa played a large rôle in negotiations between the Mexican Government and these natives, leading toward a peaceful settlement of their differences with the Government, and the acceptance of *ejidos*, and eventually of schools. Thus the knowledge Mr. Villa obtained as to these people in the last years of their isolation became an instrument in the breaking down of that isolation. The change had to come; it is fortunate that Villa's experience could be used so that the transition might be effected with relative ease.

The Guatemalan project is formulated in more general terms. The task is to survey the cultures of the western highlands, to provide a first classification of the cultures and societies there to be found, and to define a few special problems for study. The field work has been done almost entirely by Dr. Tax. His paper, published in the *American Anthropologist* for June 1937, established the *municipios* of the midwestern highlands as the essential natural societal and cultural units, in terms of which studies must be carried on. In 1934-1935 Dr. Tax began work in the *municipio* of Chichicastenango. In 1935-1936 he made brief studies of several of the communities adjoining Lake Atitlan, and initiated an intensive study of one of these, Panajachel. This study was resumed in the six months spent in the field from January to July 1937. The investigation this year proceeded from the general and statistical to a consideration of the more intimate aspects of native behavior and belief. Living in a house not unlike those of the Indians themselves,

and in the center of the Indian settlement, with the people already accustomed to the presence of strangers, Dr. and Mrs. Tax entered more fully than before into the native community. Trading with the Indians and helping them in their deals with one another, growing crops along with them, doing their bookkeeping for them and helping them in their own ways and means, all brought forth information that made more significant the market accounts and statistics, and the tables bearing on questions of production, consumption, and distribution that were otherwise prepared. Acting as godparents to Indian children, advisers to young people and their parents and in some cases even matchmakers, and aiding friends in times of sickness and death, gave the close and personal view which is essential to successful reporting of an alien social organization. Helping in, or at least witnessing, the meetings of the elders when political problems arose, did the same for political institutions. And of course participation in religious ceremonials of all kinds brought not only the natives' good will but understanding as to the relations of the sacred and the secular, of the religious and the political, and of the Christian and the pagan.

Perhaps in no branch of Indian culture, however, did the accumulation of two seasons of good will give better results than in that of folk tales. For the first time in Guatemala an aboriginal mythology was uncovered. Aside from its intrinsic interest and value (it includes origin myths, legends and tales of all kinds, and anecdotes about people living and dead) this folklore bared much of the Indian mentality difficult to uncover otherwise, and also furnished innumerable leads to previously uninvestigated fields of native belief.

Meanwhile the sociological problems previously defined were not neglected. Additional material bearing upon the nature of the *municipio* and the relations between *municipios* was gathered; also, of course, upon the nature of communal life itself in Panajachel. One important group of problems earlier recognized arises out of the fact that the midwestern highland societies are not composed solely of Indians, but also of those mixed-bloods of Spanish language and (largely) Spanish culture called *ladinos*. Earlier work in Chichicastenango and in Panajachel had established the existence of a rough three-class system, consisting of the Indians, the rural agricultural *ladinos*, and the more commercial *ladinos* of the towns. It was desirable to get a view of Lake Atitlan society from the standpoint of some of the *ladino* communities. To this end Dr. Redfield, accompanied by Mrs. Redfield, spent nine weeks in Agua Escondida, on Lake Atitlan, just above the Indian village of San Antonio and not far from Panajachel. This situation made possible frequent interchange of questions and advice between Dr. Redfield and Dr. Tax. Dr. Redfield made a short study of the *ladino* culture and society, with emphasis upon the rôles of the Indians and *ladinos* in the common society they share. This resulted in the formulation of a number of perplexing questions, statement of which will have to be deferred. The most striking single observation is the relatively slight degree to which the Indians, numerically so superior to the *ladinos*, are at present affecting *ladino* culture, in spite of the absence of race prejudice and the intimacy with which the two groups associate.

During the year two articles, summarizing results of work in the highlands, were prepared by Dr. Tax; and his plans call for the completion of a monograph on Panajachel before again taking the field. He then proposes to return to Chichicastenango for a season to complete, if possible, the work begun there in 1934-1935; but whereas at that time residence was maintained in the town itself, it is hoped that now a suitable place in the country region, where the study may be rounded out, can be found. Dr. Redfield will probably not return to Guatemala until 1938-1939.

LINGUISTIC RESEARCH—M. J. ANDRADE<sup>1</sup>

The chief aim in the linguistic research conducted in Guatemala during the first quarter of 1937 was to collect sufficient text material for a detailed description of the Mam language, the importance of which in a study of the history of the Maya linguistic stock has been pointed out in previous reports.

With the aid of the recording apparatus recently constructed for this purpose, it was possible to collect in one month texts conservatively estimated at more than 300,000 Mam words. This material is contained in 300 double-face aluminum disks, and consists of spontaneous discourse, mainly dialogues, representing the speech of informants from various parts of the Mam area, including the Tacana region, wherein the speech is known to be like that of the Mam people of Chiapas, Mexico.

Considering that he was in possession of a rather unusual amount of text material to work out the description of Mam, Dr. Andrade moved his headquarters from the Department of San Marcos to that of Huehuetenango in order to continue the survey of the languages of Guatemala undertaken in 1935. He worked on the speech of Aguacatan, listed by Stoll as one of the languages of the Maya family. Additional information was collected also on the speech of the villages north of Huehuetenango, a region concerning which Stoll's linguistic map of Guatemala is most inexact. The villages referred to are Soloma, Santa Eulalia, Barillas, San Miguel, Jacaltenango, San Juan, and others in their vicinity, where Solomec, Jacalteco, and Chuj are spoken, according to Stoll.

The language called by Stoll and others "Aguacateco" is spoken only in a small village named Aguacatan. Dr. Andrade has not studied the material collected sufficiently to pronounce on the classification of this speech, but it appears to be much like Mam, although it is totally unintelligible to a Mam. According to the native Aguacateco and their neighbors, the speech of Aguacatan is understood by no one outside their village. A similar condition exists, according to all reports, in Sipacapa, a village surrounded by Mam-speaking peoples. The speech of Sipacapa, however, has not been listed as a separate language, or even as a dialect. Of course, intelligibility cannot be the basis for determining whether or not it is justifiable to regard the speech of a locality as a separate language. If future research shows that the speech of Sipacapa is a Mam variant, that village constitutes a conspicuous exception in the Mam area, where local variants do not diverge to the point of being totally unintelligible in ordinary discourse.

<sup>1</sup> Dr. Andrade's investigation of the languages of the Maya stock is a cooperative project of the Department of Anthropology of the University of Chicago and the Division of Historical Research.



MAIZE INVESTIGATIONS—G. W. COLLINS, J. H. KEMPTON, R. STADELMAN<sup>1</sup>

As part of the research on the origin of maize and the distribution of maize relatives, Messrs. Collins and Kempton made an expedition in October 1936, through the region of Mexico where the states of Chihuahua, Durango, and Sinaloa meet. This expedition was undertaken to establish definitely the identity of a maizelike grass discovered near the town of Nobogame, Chihuahua, in 1895 by Lumholtz.<sup>2</sup>

The expedition proceeded from Santa Barbara, Chihuahua, by pack train into Nobogame via Cerro Prieto and Guadalupe y Calvo. The return trip was made through Guanacevi and Tepehuanes to Durango City. Much of the route was at elevations in excess of 9000 feet and largely through heavily forested country sparsely inhabited by primitive Tarahumare Indians.

At Cerro Prieto and at Nobogame, both approximately 7000 feet in elevation, the expedition found the maizelike grass described by Lumholtz. It proved to be teosinte (*Euchlæna mexicana*), the nearest known relative of maize. There was no evidence that the plant was utilized in the manner reported by Lumholtz. The Indians make no attempt to eradicate it from cornfields. Neither do they use the plants for forage, despite the fact that mine pack trains cause such a demand for forage that most of the common cornfield weeds are husbanded for this purpose.

At Cerro Prieto the area occupied by teosinte did not exceed half an acre and the plants found there may be the descendants of the seed transported from Nobogame as reported by Lumholtz.

The distribution of teosinte around Nobogame is more extensive than at Cerro Prieto, the plants occurring along stream banks over several square miles. Although there is unmistakable evidence that at one time the region around Nobogame was widely cultivated, this is no longer true. The Indian population has been reduced to a few families and the area occupied by maize is small.

At both Cerro Prieto and Nobogame maize fields were common and the flowering season of maize and teosinte coincided. As would be expected, natural hybrids between maize and teosinte were found in both localities. The persistence of teosinte at Cerro Prieto, where it is overwhelmingly surrounded by maize, affords a demonstration of how this plant can survive for generations and retain its identity. The question is raised as to how much of the distribution of this plant is the result of human effort.

<sup>1</sup> Participation in the Division's program of Messrs. Collins and Kempton, members of the staff of the Bureau of Plant Industry of the U. S. Department of Agriculture, has been made possible through the good offices of Secretary Wallace and of Mr. F. D. Richey, Chief of the Bureau of Plant Industry.

<sup>2</sup> Carl Lumholtz, *Unknown Mexico*, vol. 1, 429 (Chas. Scribner's Sons, New York, 1902). "Around Nobogame grows a plant called *maizillo* or *maizmillo*. It is more slender than the ordinary corn plant and the ears are very small. It grows among the corn and has to be weeded out, as it injures the good plants. However, several Mexicans assured me that, when cultivated, the ears develop. After three years they grow considerably larger and may be used as food. A man in Cerro Prieto raises this kind only; others mix it with the ordinary corn. I was told that people from the hot country came to gather it, each taking away about one almod to mix with their seed corn. The combination is said to give splendid results in fertile soil. Can this possibly be the original wild plant from which ordinary Indian corn has been cultivated?"



The discovery of teosinte at Nobogame extends the range of this maize relative 200 miles farther north than it had been known before and to that extent enlarges the possible area within which maize may have originated.

Morphologically the teosinte at Nobogame and Cerro Prieto is indistinguishable from that found not far from Durango City, where additional collections were made by the expedition. It is considered not improbable that teosinte may have been transported by man to Nobogame from the Durango region, possibly with maize.

An understanding of how ancient populations met their subsistence requirements is essential for the reconstruction and evaluation of their civilizations. Accordingly, with the object of learning as much as possible about the agriculture of the Indians now resident in the region of the Maya culture Mr. Stadelman has been stationed in the highlands of Guatemala since early January.

In choosing the site for this investigation consideration was given to the racial composition of the population, to its relative freedom from European influence, its independence of an industrial outlet, and, since aboriginal agriculture in the Americas was primarily corn-growing, to the importance of this crop in their present economy. These major considerations and a host of minor ones led to the selection of Todos Santos, an Indian village in the Department of Huehuetenango in northwestern Guatemala, as the base from which observations would be made.

The present season's corn crop, planted in January, will not be harvested until October and therefore only tentative conclusions from preliminary records are possible.

The study indicates that in the region of Todos Santos an Indian family of two adults and three children can obtain their subsistence requirements from the product of four acres with a labor expenditure of approximately 150 man-days. Evidence has been obtained that an effort is made to combat erosion on the steep mountain-side farms, and the practice of fertilizing the soil with animal manure has been adopted by some Indians.

The initiation of this investigation at this time proved fortunate, as the adoption by the Guatemalan Government of the work-book system, whereby every able-bodied adult male must prove employment for 150 days each year, or work out the difference on the public highways, will tend to standardize the time spent on the farms at this figure.

#### ANTHROPOLOGY AND HUMAN GENETICS—MORRIS STEGGERDA

Dr. Steggerda's studies of the living Maya of Yucatan, which have been made possible by cooperation of the Institution's Department of Genetics, were continued.

Dr. Steggerda has previously reported a lower incidence of dental caries in the Yucatan Maya and the Navajo Indians than in Dutch whites in Michigan and in other white groups reported in the United States. This season Dr. T. J. Hill, of Western Reserve University, checked Dr. Steggerda's findings in Yucatan and in addition showed that the percentage of Maya Indians free from *Bacillus acidophilus* was considerably higher and the number of these bacteria in individual mouths was relatively lower than for whites in

the United States. These results are extremely important in that they support the theory that tooth decay in humans is directly related to the presence of *B. acidophilus*. The diet of these Indians, previously shown to be largely carbohydrate, should not deter the growth of these organisms.

The 150 Maya children who constitute part of the problem on comparative growth in different races have now been measured for seven consecutive years. Since many are now married and have children of their own, Dr. Steggerda feels that the field work is now complete and the data are ready for analysis.

The agricultural survey of the Maya will require one or two more seasons; however, at present it is possible to supply the following facts: The average size of Yucatan *milpas* is 99.23 *mecates* or 9.8 acres. The yield per *mecate* is still indefinite, but it may be fair to consider it as one *carga* per *mecate*, or 17 bushels per acre. An average family of five individuals consumes 6.65 pounds per day or approximately 64 bushels per year. It was determined that it takes 9 hours on the average to produce one bushel.

Family statistics are also available showing that the average number of children per woman whose reproductive life is complete is 8.14. The reproductive span for 39 women was found to be 16 years. The average age of Maya girls at marriage is 16.3 and their age at the birth of their first child is 17.8. The average interval between births is 27 months.

In last year's report were discussed the medical usages, by the Colonial and modern Maya, of 25 Yucatecan plants. This year 100 additional medicinal plants were studied. Dr. Steggerda's tabulation now also lists other plants used by the modern Maya for food, lumber, and miscellaneous purposes.

Cooperative projects dealing with problems on the psychology of the Maya are in progress.

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Additional investigations forming part of the Maya program are recorded in the reports of the Sections of Post-Columbian American History and of the History of Science, as follows: History of Yucatan, pp. 155-157; Study of Maya Colonial documents, pp. 157-158; Maya astronomy, pp. 158-159.

#### SOUTHWESTERN RESEARCH—E. H. MORRIS

From July until December 1936, E. H. Morris was occupied with the completion of a monograph on the archaeology of the La Plata district in southwestern Colorado and northwestern New Mexico. This paper presents results of field work done intermittently for various institutions during the past twenty years and covers the material aspects of culture progression in the La Plata country from Basket Maker III to the close of Pueblo III (A.D. 1300  $\pm$ ), a period of approximately 700 years.

Since December, Mr. Morris has been engaged in study of materials from cave sites in the Red Rock district of northeastern Arizona excavated for Carnegie Institution in 1931. Dates for these caves have been established by Drs. Douglass and Haury to cover the interval from A.D. 477 to approximately A.D. 700. Aside from a considerable series of unfired clay con-

tainers and a large number of pottery vessels of the earliest types made in the region, the collection is rich in perishable materials such as basketry, textiles, and wooden artifacts, which in most localities have been claimed by decay. Eventual publication on the Red Rock sites and their contents will present a comprehensive picture of a relatively early and very important stage in Southwestern culture history.

Under the joint auspices of Gila Pueblo, Peabody Museum of Harvard University, and the Division, Dr. George Woodbury is making an intensive study of all skeletal material from the earlier cultural groups of western United States: Basket Makers, Cave- and Bluff-Dwellers, etc. He is also examining such osseous remains as have been attributed, because of typological peculiarities or from the circumstances of their occurrence, to geologically ancient man in America. Dr. E. A. Hooton, of Harvard, is in general charge of the work, which is in the final year of a three-year program. Dr. Woodbury has completed observation and measurement of all available specimens, and is now engaged in analysis of the large amount of raw data collected.

PUBLICATIONS, SECTION OF ABORIGINAL AMERICAN HISTORY—  
MARGARET W. HARRISON

In October 1936 *Zacualpa: A study of ancient Quiché artifacts*, by S. K. Lothrop, was published. This illustrated volume describes and classifies minor antiquities from the highlands of Guatemala, particularly those from the ruins of Zacualpa.

Volume III of "Contributions to American Archaeology" closed with R. E. Smith's *Study of Structure A-I complex at Uaxactun, Guatemala* (No. 19), published in March 1937. Volume IV is also complete and embraces four papers. In March was preprinted *Structure A-XVIII, Uaxactun* (No. 20), by A. L. Smith. Early in June the three last papers of volume IV appeared together. Hermann Beyer, of the Department of Middle American Research at Tulane University, presented his *Studies on the inscriptions of Chichen Itza* (No. 21). J. Eric Thompson contributed *A new method of deciphering Yucatecan dates with special reference to Chichen Itza* (No. 22). J. H. Kempton, of the Bureau of Plant Industry, U. S. Department of Agriculture, collaborated with Wilson Popenoe, of the United Fruit Company, in producing *Teosinte in Guatemala* (No. 23).

Progress has been made throughout the year toward publication of the report by Oliver G. and Edith B. Ricketson on the first five seasons' excavations at the ruins of Uaxactun, Guatemala, with appendices by Monroe Amsden, H. E. D. Pollock, and A. L. Smith. Part I, by Mr. Ricketson, contains an extensive introduction, a history of the expeditions to Uaxactun, and a detailed report on the excavations and anthropological material recovered, with discussion of sequences in building construction. In part II Mrs. Ricketson has described and classified the artifacts. It is expected that *Uaxactun, Guatemala, Group E—1926-1931* will be ready in September 1937.

The second part of a projected trilogy concerning the hieroglyphic inscriptions of the ancient Maya is now in press. In *The inscriptions of Petén*



S. G. Morley has given for each known inscription a location, description, and date whenever possible. This compendious monograph is expected to appear early in 1938.

Robert Wauchope has completed the manuscript of a fully illustrated volume to be entitled *Modern Maya houses: A study of their archæological significance*. Mr. Wauchope treats in detail village planning and house construction, with notes on the sociological aspects of the dwellings and on native architectural terminology.

## SECTION OF POST-COLUMBIAN AMERICAN HISTORY

### HISTORY OF UNITED STATES

The eighth and last volume of Dr. Edmund C. Burnett's *Letters of members of the Continental Congress* was published in September 1936. This book completes a series inaugurated in 1921, and containing a total of 6125 letters, which, arranged chronologically, throw light upon the transactions of the Continental Congress throughout the entire period of its existence (1774-1789), during which time it sat with closed doors. The last volume includes a supplement of 30 letters from the years 1783-1784. Dr. Burnett is at present preparing a general or interpretative volume on the Continental Congress. In November 1936 he read a paper, "Southern statesmen and the Confederation," before the Southern Historical Association at Nashville, in the main a product of the studies for the proposed volume.

After the publication of his *Guide to the materials for American history in Russian archives* in 1917, Dr. Frank A. Golder, late professor of history and a director of the Hoover War Library at Stanford University, made supplementary notes in Petrograd relative to the correspondence between the Russian diplomatic agents in America and the Russian Foreign Office. This supplement, continuing the correspondence from 1854 to 1870, was published as volume II of the *Guide* in March 1937.

The series entitled *European treaties bearing on the history of the United States and its dependencies*, the first volume of which appeared in 1917, was finished with the publication of the fourth volume in June 1937. For all the treaties in volumes I and II and for most of those in volume III the editor, the late Miss Frances G. Davenport, wrote introductions which made an approach to a consecutive history of European diplomacy respecting America down to 1713. Each treaty in the first three volumes is preceded by an extensive bibliography. Miss Davenport's death prevented the completion of the work on the last six treaties in volume III. These, as well as the documents in volume IV, were supervised by the late Dr. J. Franklin Jameson. The documents for volume IV were edited by Dr. Charles O. Paullin, now retired from this Division.

The series comprising *Judicial cases concerning American slavery and the Negro* was likewise completed with the publication of the fifth volume in July 1937. These cases, illustrating the history of the Negro and of American slavery as an actual working institution, as well as presenting aspects of American law and its development from the earliest time to 1875, were edited by the late Mrs. Helen Tunnicliff Catterall. Her death left unfinished



some material for volumes IV and V, which were completed by Dr. James J. Hayden, a member of the faculty of the Catholic University Law School and of the District of Columbia and Maryland bars.

Another series which will reach completion during 1937 is the *Historical documents relating to New Mexico, Nueva Vizcaya, and approaches thereto, to 1773*. These documents illustrate the history of the Rio Grande region from the first explorations of it by the Spaniards to 1773. Collected by Adolph F. A. and Fanny R. Bandelier, they have been edited by Dr. Charles W. Hackett, professor of Latin American history at the University of Texas. The first two volumes include the Spanish texts accompanied by English translations; the third and final volume contains translations only. Dr. France V. Scholes, of this Division, has given much time and advice for the preparation of volume III, which is expected to appear in the early fall of 1937.

The fourth volume of Dr. Leo F. Stock's *Proceedings and debates of the British Parliaments respecting North America* will be published in November 1937. This series, planned to contain all available contemporary records, in print or manuscript, of parliamentary proceedings in England, Scotland, and Ireland concerning North America, begins with the year 1542 and will end with the acknowledgment of American independence in 1783. The fourth volume, now in press, carries the records down to 1739.

During the months of August and September 1936, Dr. John J. Meng, instructor in politics at the Catholic University of America, conducted researches in the archives of the French Foreign Office for the continuation of the *Guide to materials for American history in the libraries and archives of Paris*, the first volume of which was published in 1932. Working under the general supervision of Dr. Waldo G. Leland, editor of the *Guide*, Dr. Meng has written the first draft of the final manuscript of material in the Foreign Office listed under the classification "Correspondance Politique, États-Unis" for the entire period covered by the *Guide* (1774-1860). He is about to begin work on the series "Mémoires et Documents, États-Unis," which should be completed during the summer of 1937. After other portions of the Foreign Office material have been examined, it is expected that much of the manuscript for volume II should be ready for publication early in 1938.

The annual *List of doctoral dissertations in history in progress at American universities* was compiled by Margaret W. Harrison, editor of the Division. The issue for 1936 was extensively enlarged and revised. This pamphlet is published by the Division and distributed to libraries, educational institutions, members of university faculties, and periodicals in the field of history.

Mr. David M. Matteson, indexer of publications emanating from the Section of Post-Columbian American History, has prepared the indexes to five volumes mentioned above, namely, *Letters of members of the Continental Congress* (VIII), *Guide to the . . . Russian archives* (II), *European treaties* (IV), *Judicial cases* (V), and *Proceedings and debates* (IV).

## HISTORY OF YUCATAN

Dr. Robert S. Chamberlain, who is preparing a detailed study of the conquest of the entire Maya area, spent the summer of 1936 in Yucatan and Guatemala carrying on investigations in the local archives. In March 1937 he returned to Central America to continue his investigations. The reorganization of the archives of Guatemala now in progress made it impossible to search certain local collections, but except for these Dr. Chamberlain's work in the Guatemala archives has been completed. A rapid survey of the principal archives of Honduras and El Salvador has also been made. Although the materials for the period of the Conquest in these collections are not numerous, important documents have been found that fill in lacunæ in the papers in Seville.

The archives of Guatemala City are rich in materials for the later colonial period, and Dr. Chamberlain has prepared a brief report dealing with archival organization at the present time and indicating the general nature of the contents of the individual archives. This report will be extremely useful for students of the local history of Guatemala and for those interested in general problems of Spanish colonial policy and administration in the New World. It will be printed in the *Handbook of Latin American studies* for 1937.

During his stay in Yucatan in the spring of 1937 Dr. Chamberlain spent some time at Chichen Itza in conference with Dr. Morley and Mr. Roys, and together with Mr. Roys he made a brief reconnaissance of the area east of Tizimin. At the site of Dzonot Ake ruins were found. Information was also received which should be useful in identifying the site of Chuac-ha.

In April Dr. Chamberlain and Mr. Ruppert visited Tixchel near Sabancuy. Tixchel was an important pre-Conquest site resettled during the second half of the sixteenth century by groups of Chontals from the Acalan area. The exact location of the village of Acalan is still undetermined. Documents of the sixteenth century clearly indicate that the Candelaria drainage formed an important part of the *cacicazgo* of Acalan-Tixchel, and Chamberlain and Ruppert made a short trip up the Candelaria. Although ruins exist at several points on the middle and upper parts of the river, none could be identified as Acalan.

Dr. Chamberlain will spend the summer of 1937 working in the archives of Mexico City. He also hopes to visit Chiapas before he returns to the United States in the autumn.

Sr. J. Ignacio Rubio Mañé has spent the year 1936-1937 in Mexico City carrying on investigations in the Archivo General y Público de la Nación and in the Biblioteca Nacional. The Inquisition papers in the Archivo General contain a mass of Yucatan material, and copies or extracts have been made of all the documents *ante* 1580. These data will be incorporated in the volume on the life and times of Fray Diego de Landa being prepared under the direction of Mr. Scholes.

The Sección de Civil of the Archivo General contains 2302 volumes of uncatalogued papers for the entire district administered by the *audiencia* of

Mexico. They consist of suits before the *audiencia*, *residencias*, reports, etc., that are of great value for every phase of the administrative history of New Spain. Up to the present time Sr. Rubio Mañé has examined 1250 volumes in this series and has found important items for the history of Yucatan. The most valuable finds to date are (1) records of the Palacios *visita* in the 1580's, and (2) documents pertaining to the Yucatan phases of the *visita* of New Spain by Galvez in the eighteenth century. In addition to these outstanding groups of papers there is a mass of material on *encomiendas*, Indian labor, and land administration. The Sección de Tierras, consisting of 3692 volumes, of which 2971 have been catalogued, supplements the materials in the Sección de Civil. Most of the Yucatan documents, as indicated by the catalogue, deal with the eighteenth and nineteenth centuries.

In the Sección de Historia items have been found dealing with the population of Yucatan in the late eighteenth century and with the organization of schools during the same period. In the Biblioteca Nacional the most important find was a report on general conditions in Yucatan made as the result of the *visita* of the province in the time of Galvez. This document, which supplements similar papers in the Sección de Civil, is being published by Sr. Rubio Mañé in the *Diario de Yucatan*.

Mr. Scholes and Miss Adams have been engaged in preparing several groups of materials for publication. In collaboration with Sr. D. Carlos Menéndez, editor of the *Diario de Yucatan*, a volume of documents on the history of Yucatan, 1550-1561, has been published, and a second volume of documents on the organization of the Church and the missions, 1560-1610, is now in press. Two volumes of documents dealing with the administration of the *alcalde mayor* Don Diego de Quijada, 1561-1565, and with the famous *auto de fe* of 1562 will be ready for the press in October. These volumes will provide the documentary background for the essay on the life and times of Fray Diego de Landa to be issued in conjunction with the translation of Landa's *Relación de las cosas de Yucatan* to be published by Professor A. M. Tozzer, of the Peabody Museum of Harvard University.

Work on the Acalan-Tixchel volume was postponed pending the report of the reconnaissance of Dr. Chamberlain and Mr. Ruppert up the Candelaria River. It is now clear that a thorough exploration of the area south of Terminos will be necessary before the Acalan question can be finally solved. Inasmuch as such a reconnaissance will not be made for some time, the volume on the *cacicazgo* of Acalan-Tixchel will be pushed to completion during the coming year.

Dr. Chamberlain and Mr. Scholes are collaborating on a paper on population problems in Yucatan prior to 1550 which should be completed within a few months. Progress has been made on the first section of the study of the *encomienda* in Yucatan.

All these documentary publications and monographs are preliminary to the first two volumes of the general history of Yucatan, 1550-1810, which forms the major objective of the researches of Mr. Scholes, Miss Adams, and Sr. Rubio Mañé. But the discovery by Sr. Rubio Mañé of such a large mass of documentary material in the archives of Mexico means that a thoroughgoing examination of these papers will be necessary before this



larger study of Hispano-Indian society and administration in Yucatan can be put in final form.

STUDY OF MAYA COLONIAL DOCUMENTS—R. L. ROYS

Much of the period under review has been spent by Mr. Roys in completing the translation and annotation of the papers found in the municipal archives of Ebtun in eastern Yucatan.<sup>1</sup> An introduction has been written summarizing the historical and ethnological material contained in these documents and reviewing the social, economic, and local political development of this region during the Spanish colonial period.

In collaboration with Mr. Scholes, a preliminary study of the Acalan-Tixchel area has been made, also annotations to the Spanish version of the history and service record of the caciques of this region,<sup>2</sup> in the light of a comparison of this document with the original Chontal text.

During the late winter and spring of 1937 Mr. Roys was in Yucatan. Accompanied by Dr. Steggerda, he made a journey along the border of the southern Cupul area and the former Province of Coahuah. The line was found to extend from a point about 10 km. south of the west end of the ancient Coba-Yaxuna road in an easterly and southeasterly direction.

This old frontier was located from watering places and other sites hitherto unmapped but cited in the early post-Columbian Maya documents. Many portions of the former boundaries separating the Provinces of Ah Canul, Mani, Sotuta, and the Cupuls are remembered by the present-day Indians; but consciousness of a geographical division between the southern Cupul and the Coahuah areas no longer exists among the present Indians living in this region. During the War of the Castes the native rebels occupied this part of the Coahuah area for a considerable time. Finally, when the remainder of them retreated to the forests of Quintana Roo, the district was resettled by immigrants from the neighborhood of Valladolid. People interviewed at Chikindzonot and Ekpedz, formerly important Coahuah towns, had come from near Valladolid and were apparently unaware that their new homes were in what had formerly been a separate territorial entity.

Some time was spent at Chicxulub and Yaxkukul in northwestern Yucatan, in order to locate the boundaries of their lands. These are described in the sixteenth-century Maya manuscripts of the Pech family, photographs of which were secured by Dr. Morley during the past year. Although the chief interest of these papers lies in the important historical material which they contain, they were primarily land documents; and an adequate presentation of them is hardly possible without a topographical knowledge of the territory which they cover.

This district is now given over to the cultivation of sisal hemp, and the old agricultural life, so much in evidence in many parts of Yucatan, has greatly changed. Maya is still the language of most of the people, but a considerable Spanish admixture is to be seen in the population. There is even an occasional structure of sawn lumber among the Maya pole-and-thatch houses and the stone buildings of Spanish type.

<sup>1</sup> Year Book No. 35, p. 142.

<sup>2</sup> *Ibid.*, p. 150.



In view of the former political importance of the Province of Ceh Pech, the pre-Spanish remains of the region were noted with interest. At one ruined site close to Chicxulub, the massive character of the masonry suggests a resemblance to that of Aké, 30 km. to the southeast.

From Uxmal neighboring sites of historical interest were located; and a trip was made across the sparsely inhabited intervening country to Becal, in order to locate the boundary between the Provinces of Mani and Ah Canul.

Dr. Chamberlain came to Chichen Itza, giving opportunity for a profitable conference regarding the relations between the study of Maya manuscripts and that of the history of Yucatan, in which he is collaborating with Mr. Scholes. In his company Mr. Roys made a trip to northeastern Yucatan to visit the scene of one of Montejo's first important battles with the Maya.

## SECTION OF THE HISTORY OF SCIENCE AND ALLIED INVESTIGATIONS

### HISTORY OF SCIENCE—GEORGE SARTON<sup>1</sup>

*Introduction to the History of Science*—The preparation of volume III, dealing with science and learning in the fourteenth century, has advanced considerably during the past year. It is hoped that the Latin and European part (by far the largest one) will be completed before the end of 1937. The very important Jewish part is already completed. When the Latin part is ready, it will then suffice to revise the Byzantine, Arabic, and other oriental notes. The Chinese and Japanese notes will cause special difficulties, as no collaborator has yet been found able and willing to revise them. All the notes not only for the fourteenth century but also for the fifteenth century have been ready for many years, but they are being gradually rewritten on a larger scale, all facts being investigated more fully than could be done the first time. The above remarks refer only to the analytical stage of the work. According to Dr. Sarton's method, no attempt at synthesis will be made until after the analysis of all the materials has been perfected in every possible way.

Dr. Welborn has devoted most of her time to the revision and amplification of the Latin notes; and Dr. Pogo has continued astronomical studies bearing on the problem of correlation of Maya and Christian chronologies. His report follows:

*Maya Astronomy*—The astronomical table preserved on pages 51–58 of the Dresden Codex may be considered as consisting of two sets of data: first, of a table of eclipse syzygies; second, of a group of ten "pictures." The hypothesis that the "pictures" referred to lunar—and not to solar—eclipses actually observed in the Maya territory has yielded an unexpectedly large number of theoretically possible correlations, mentioned in the previous report. A study of the table of syzygies proper, i.e., of the numbers and dates which form the calendrical framework for the "pictures," has led to some interesting results. It has been found that the empirical data—the

<sup>1</sup> Nineteenth annual report for the period extending from July 1, 1936 to June 30, 1937 (previous reports appeared in Year Books Nos. 18–35, 1919–1936; the twelfth and following also appeared in *Isis*, the latest in vol. 26, 139–146, 1936).

dates of actually observed lunar eclipses, and the intervals and combinations of intervals between these dates—which are necessary for the construction of a Maya table of syzygies could have been collected in a very short time. A list of all the lunar eclipses which could have been observed, within the limits of the Maya territory, during one-third of a century—the approximate duration of the Maya eclipse cycle of 11,960 days, or the average useful life of a priest-astronomer—would furnish enough data for the construction of an almost complete framework of intervals showing all the essential features of a Maya table of eclipse syzygies. The hypothesis that the tabular framework, like the “pictures,” is based on lunar, and not on solar, eclipses actually observed by the Maya, is simpler than the assumption that the Maya were not interested in lunar eclipses and that they spent many centuries in accumulating solar eclipse data for their table of syzygies; incidentally, a table of the Dresden Codex type could have been constructed by astronomers whose knowledge of the length of the synodical and of the nodical months and whose ability to handle fractions may be assumed to have been rather limited. The omission, in the Maya table of eclipse syzygies, of a number of theoretically possible syzygies may lead to the determination of the empirical set or sets of data used in the construction of the table, thus giving us a *terminus post quem* for the origin of the Dresden Codex table, and an additional criterion for the elimination of some of the correlation possibilities offered by the “picture” intervals.

While the solution of the elusive correlation problem remained the main purpose of the Dresden Codex studies, an investigation of the Supplementary Series in general, and of the lunar calendar of the Maya in particular, was carried on from a new point of view—as a Maya contribution to comparative calendariography. The Maya equivalents or analogies of such chronological devices as the Roman Indiction, the Epact, the Golden Number, etc., appear, in the light of this investigation, as gradual discoveries, made by various Maya astronomers, of chronologically useful or of merely curious properties which were inherent in their calendar system. A deeper insight into the development and the structure of the Maya calendar may be useful to workers on the correlation problem.

*Other Investigations*—Dr. Sarton’s teaching in Harvard University, especially the direction of his seminar and his guidance of special students, oblige him to devote a part of his time to investigation of various topics of the history of science far remote from the fourteenth century. The range and diversity of these is apparent from the list of his writings. It may be remarked, in this connection, that though much time is thus taken from the main work, that time is far from lost even from the point of view of that work. A historian of science whose knowledge was restricted to the fourteenth century would be a very poor historian of that century.

*Editing of “Isis” and “Osiris”*—Many correlated activities are involved in the editing of *Isis* and *Osiris*, and the publication in *Isis* of a critical bibliography of all the writings anent the history and philosophy of science. As far as Carnegie Institution is more immediately concerned, these writings can be divided into three groups, dealing respectively: (A) with the period extending from the time of Homer to that of Roger Bacon, (B) with the

fourteenth century, (C) with later centuries. The notes of group A are in the form of errata and addenda to volumes I and II of the *Introduction*; those of group B are materials for volume III (generally used by the author in advance of their publication in *Isis*); those of group C are materials for the subsequent volumes.

During the year 1936-1937, four numbers of *Isis* were published (70 to 73), forming volume 26 and halves of volumes 25 and 27, plus one volume (vol. II) of *Osiris*, devoted to the longer memoirs: a total of 1697 pages, 25 plates, 88 figures and facsimiles, containing 61 memoirs, 38 shorter notes, 103 reviews, and 2070 bibliographical items. No other reviews in the world perform a similar service with the same completeness and catholicity. *Isis* is not merely a vehicle for new facts and new ideas in its field, but also a clearing house of information for every fact and idea concerning the history of science, wherever it may be published and in whatever language. Thus it is at one and the same time the best tool for any student engaged in these studies, and the best means of establishing them as an independent discipline on a high level of scholarship.

#### HISTORY OF GREEK THOUGHT—W. A. HEIDEL

During the year steady progress has been made by Dr. Heidel in his study of early Greek philosophical and scientific thought. About one-half of the text is now typed, and the remainder is considerably advanced toward completion. Certain minor questions in the general field have been discussed in reviews of several important books that treat of related subjects; and the fundamental questions relating to the history and development of Greek geography have been considered at length in his book, *The frame of the ancient Greek maps with a discussion of the discovery of the sphericity of the earth*, which was published in June 1937 by the American Geographical Society as No. 20 in its Research Series. It is believed that in part I, for the first time, the principles are disclosed on which the Greeks constructed their general maps before the earth was conceived as a sphere. In part II, Dr. Heidel has attempted to determine as definitely as possible the date of this epoch-making discovery, and to show how the frame of the maps constructed on the assumption that the earth was a circular disk was adapted to the new conception of the earth.

# MOUNT WILSON OBSERVATORY

WALTER S. ADAMS, DIRECTOR

FREDERICK H. SEARES, ASSISTANT DIRECTOR

The rapid increase in solar activity and the near approach to sun-spot maximum have expanded greatly the scope of solar investigations during the past year. Especially has this been true of the bright short-lived eruptions which often reach maximum brightness within a few minutes. The development of methods for keeping the sun under nearly continuous observation for long periods of time has led to interesting conclusions regarding the connection of solar eruptions with radio fade-outs and magnetic storms upon the earth. The effectiveness of such eruptions in producing fade-outs depends mainly upon their intensity and not upon their position on the solar disk. The eruptions are high-level phenomena, visible not only in hydrogen light but in that of calcium and some other metals, and cover relatively small areas of the sun's surface, generally but not always near active sun-spot groups.

Detailed studies of the motions in eruptions as well as in eruptive and other types of prominences have been made by Pettit with the equipment at the McMath-Hulbert Observatory. The eruptions appear to be exceptionally bright gaseous masses which burst through the chromosphere and rise and fall with great rapidity. Such an eruption observed on August 8, 1936, rose to a height of 80,000 km with a velocity of 240 km/sec. The chromosphere itself is seen to be in continual motion, rising and falling like ocean surf on a coast.

Knots and streamers in eruptive prominences have occasionally been observed to distances of 200,000 km from the sun's edge. Sometimes complete loops are seen, with the gases rising from a spot area and returning to it like a fountain; but the trajectory in eruptive prominences is usually so narrow and tall that the prominence fades out before the trajectory is completed.

Sun-spot activity has been high throughout the year, and there have been no days on which spots were not visible. The number of spot-groups observed in 1936 (459) exceeded the numbers in the maximum years of the last two cycles, 450 groups in 1917 and 424 in 1927. Since the maximum is not expected before the end of 1937, the present cycle should be an exceptionally active one. The reversal of polarity of the magnetic field in spots which occurred at the last minimum has continued as anticipated, and only 2 per cent of the spots observed show polarities of irregular sign.

An extension of the region photographed in sun-spot spectra to about  $\lambda 8850$  shows many new spot lines and a very interesting group near  $\lambda 8715$ , probably of molecular origin, which appears to have a reversed Zeeman pattern with separations about one-quarter of those of atomic lines in this region.

Among the numerous solar investigations completed during the year has been the measurement of the relative intensities of lines of hydrogen and ionized calcium across the disk. The radiation within these lines falls off toward the limb less rapidly than that of the adjacent continuous spectrum, the difference being 7 per cent for hydrogen and 25 per cent for calcium. An allied investigation was the measurement of the absorption produced by the



Fraunhofer lines for each 100 Å between  $\lambda 3500$  and  $\lambda 5000$ . Factors amounting to 1.64 near H and K and 1.15 near  $H\beta$  must be applied to the observed energy-curve of the sun to correct for line absorption.

In the infrared solar spectrum progress has been made on the separation of solar from terrestrial lines and the measurement of wave-lengths, and some new identifications have been established, among them the fundamental series of sodium lines and the first member of the principal series of lithium at  $\lambda 6707$ .

Extensive measurements of the telluric lines perhaps chiefly of water vapor and molecular oxygen have given interesting results. A faint band near  $\lambda 6300$  superposed upon the  $\alpha$  band of oxygen has been identified as due to water vapor but exhibits some marked peculiarities. A telluric band  $\lambda 5600$ – $\lambda 5800$  varies in strength quite differently from the bands of water vapor or oxygen, and while its origin may be associated with the  $H_2O$  molecule it cannot be due to water vapor in the physical state producing the well-established infrared bands. Visual observations have confirmed the existence of a faint band near  $\lambda 5035$  which was first discovered by Ångström. Its origin must be regarded as uncertain. Two new bands of ordinary oxygen  $O^{16}O^{16}$  near  $\lambda 6970$  and  $\lambda 6370$  have been identified, and another band in the green is under investigation. An interesting application of the measures of the molecular oxygen lines is a new determination of the internuclear distance in the molecule. This indicates a slight reduction of the distance in the isotopic molecule  $O^{16}O^{18}$  relative to the ordinary molecule in the excited state but not in the normal state.

In continuation of an extensive investigation, the intensities and contours of 340 spectrum lines at the center and the limb of the sun between  $\lambda 5400$  and  $\lambda 5900$ , with Rowland intensities of from  $-1$  to  $8$ , have been measured with the microphotometer. A study of the atmospheric oxygen bands A, B, and  $\alpha$  by Mr. Allen has enabled him to determine the effective collision diameter of the molecule  $O_2$  in air as  $4.2 \times 10^{-8}$  cm, and the absorption coefficients of the bands A and  $\alpha$  relative to B as 13.5 and 0.039, respectively. The corrections to the resolving power of the spectrograph derived from the oxygen lines were applied to 91 solar lines which were found to be wider than theory predicts, unless the sun's reversing layer is subject to turbulent velocities of the order of 1.6 km/sec.

Thermoelectric measurements confirm an earlier conclusion that the ultraviolet solar radiation outside the atmosphere is sensibly constant within the interval  $\lambda 0.38 \mu$  to  $\lambda 0.325 \mu$  and somewhat less than one-half the maximum intensity at  $\lambda 0.48 \mu$ .

A new determination of the solar temperature by Dr. R. B. King, based upon laboratory  $f$ -values and equivalent widths of a large number of  $Ti I$  lines, gives a value of  $4400^\circ \pm 100^\circ$  K for the level in the reversing layer at which these lines are absorbed most effectively.

Two investigations which promise interesting results are those of the spectrum of the corona and the flash photographed at the total solar eclipse on June 8, and the application of the interference spectrograph to the determination of the solar parallax through observations of the fringes in a bright-line nebula.

Dr. F. E. Wright has nearly completed his extensive measurements of the amount of plane polarization introduced into light reflected and diffracted from the surface of the moon. Comparison with terrestrial substances supports the previous conclusion that the surface materials of the moon are of the nature of volcanic ash and pumice high in silica content.

Planetary investigations have included direct photographs at the coudé focus of the 100-inch telescope on Kodachrome films, which give nearly grainless images in color that show considerable detail, and a study of water-vapor lines near  $\lambda 7200$  in the spectrum of Mars. At the center of the disk there is no evidence of any Martian lines of water vapor. If present, their intensity must be less than 5 per cent of that of the corresponding terrestrial lines.

In the field of trigonometric parallaxes eight stars have been found with photographic absolute magnitudes greater than  $+10$ , two of which are faint companions of dwarf stars and have absolute magnitudes below  $+15$ . The measured parallax of the white dwarf BD  $+70^{\circ}8247$  is  $+0''.048$ .

The measurement of duplicate photographs of 222 fields centered about known stars of large proper motion has resulted in the discovery of 100 stars with motions exceeding  $0''.050$  a year. Seventeen new companions to the central stars have been found with distances ranging from  $2''$  to  $738''$ , and photographic absolute magnitudes from  $+10.2$  to  $+14.7$ . Apart from these companions, only two stars in all these fields have proper motions exceeding  $0''.50$  annually.

An analysis of the parallaxes of stars of large proper motion indicates that in the neighborhood of the sun the maximum frequency of stars lies at absolute magnitude  $+12.7$  and that the density is about 1 star per 5 cubic parsecs.

The measurement of the photographic magnitudes of stars north of  $+80^{\circ}$  as a supplement to the standards of the Polar Sequence has been completed and much of the photovisual material is also finished. A comparison of the international magnitudes of about 30 stars in the North Polar Sequence with the photoelectric magnitudes and colors measured by Stebbins and Whitford shows certain systematic discrepancies. A modification of the reduction for differences in color sensitivity removes all important differences between magnitudes 6 and 11. The remaining discordance of about 0.1 mag. affecting four of the brightest stars is to be ascribed, in part at least, to the influence of hydrogen absorption, which is quite different for the two systems employed. Of especial importance for the determination of very faint photometric standards has been the work of Baade in establishing the value of the platinum half-filter for such investigations. Since exposures with and without the filter are simultaneous, the effects of varying seeing are eliminated.

Additional measurements of the colors of faint B-type stars by Stebbins and Whitford show color excess for practically all such stars in the bright clouds of Sagittarius and indicate the presence of a thin veil of obscuring matter throughout this region of space.

Two investigations of stellar parallaxes and luminosities have given important results. Strömberg has developed a method of grouping stars ac-

cording to reduced total proper motion and, within each group, deriving the mean absolute magnitude and dispersion in magnitude from trigonometric parallaxes. Application to stars of spectral types G8-K2 shows at once the clear distinction of the classes ranging from dwarfs to supergiants. The method also gives the distribution in absolute magnitude, which is found to agree well with that derived from a comparison of the distribution of proper motions with that of radial velocities.

An extensive analysis by Russell of the trigonometric and spectroscopic parallaxes of 700 giants and 1100 stars of the main sequence indicates a very satisfactory agreement in zero point for the two systems. The calibration can be slightly improved by increasing the differences between the spectroscopic absolute magnitudes and the mean values for each spectral subclass by 7 per cent for the giants and 16 per cent for stars of the main sequence. The accidental errors of the spectroscopic determinations appear to be somewhat larger than first supposed and are under investigation.

Successful measures have been obtained with the 50-foot interferometer of the angular diameters of four red giant stars,  $\beta$  Andromedæ,  $\alpha$  Ceti,  $\alpha$  Orionis, and  $\alpha$  Scorpii. The spectroscopic binary  $\beta$  Capricorni has shown no evidence of duplicity when examined with a mirror separation of 40 feet.

An interesting automatic guiding device developed by Whitford and Kron was found to operate satisfactorily with the 60-inch telescope on stars brighter than magnitude 8.6. Further increase in sensitivity must depend upon improvements in the photosensitive cathode and its associated amplifier.

In the field of stellar spectroscopy measurements of radial velocity have been continued regularly, and results for about 600 stars are now available. Several spectroscopic binaries have been investigated, among others the interesting triple star  $\beta$  Capricorni, for the components of which Sanford has derived periods and minimum values of the masses.

A study of 190 Cepheid variables down to the fourteenth photographic magnitude based upon more than 1000 spectrograms has been brought to completion. Velocity-curves have been drawn for 106 stars. The results show a marked correlation between length of period and velocity-range. Maximum velocity of approach occurs somewhat later than maximum of light, and maximum velocity of recession later than minimum of light, the mean lag being about 7 per cent. A few Cepheids in globular clusters have been observed successfully.

Spectrograms of the long-period variable  $\alpha$  Ceti taken with the coude instruments show in the region  $\lambda 3600$ - $\lambda 3900$  a large number of previously unobserved emission lines; many of which are due to  $Fe\ I$ . Some of the emission lines in this class appear to be due to atoms raised to a particular level by a chance coincidence of a line from a ground, or very low, level with a very strong line of some other element. On this hypothesis the  $Mg\ II$  lines  $\lambda 2796$  and  $\lambda 2803$  would provide the exciting radiation for the two important emission lines of iron,  $\lambda 4202$  and  $\lambda 4308$ .

Observations of a few of the brighter stars with the highest dispersion and resolving power of the coude spectrograph have resulted in the discovery of double and asymmetrical lines in the spectra of  $\alpha$  Orionis and  $\alpha$  Scorpii and in the resolution of the interstellar from the stellar H and K lines in  $\alpha$  Cygni.



The same spectrograph used with a Schmidt camera has given spectra of a number of early-type stars as far as  $\lambda 3050$  which show many new lines of highly ionized elements.

Investigations of novæ have included a detailed spectrophotometric study of some of the most important features of the spectrum of Nova Herculis (1934), among them the absorption components of the D lines, as well as other dark lines, and the emission lines of *Fe* II and [*O* I]; and observations of the velocity-curves and chief spectral characteristics of Nova Lacertæ (1936) and Nova Sagittarii (1936). These stars showed velocities among the highest ever observed among novæ. Observations were also obtained of the two novæ in Aquila discovered in 1936, and of the fainter novæ of former years.

An extensive series of measurements of the intensities of the interstellar H and K lines of calcium and the D lines of sodium in the spectra of 404 early-type stars has been completed. Study of the distance-intensity relationship in 23 areas in the sky has revealed no great regional differences. The form of the relationship out to a distance of 2000 parsecs has been determined from the D lines. Although galactic rotation seems to be of minor influence in producing the observed intensities of the D lines, its effect is plainly marked in the observed displacements of lines in stars of different longitudes. A study of the relative intensities of D1 and D2 leads to the conclusion that the properties of sodium cannot be identical at all points in interstellar space, and, when considered in conjunction with the effect of galactic rotation, suggests the presence of discrete clouds of sodium gas which are several hundred parsecs across and have appreciable random velocities. An upper limit of  $40,000^\circ$  is found for the temperature of the interstellar sodium gas and a value of about  $10^{-31}$  gr/cc for the density. The structure and the mean wave-lengths of the unknown diffuse interstellar lines in the yellow and red have also been studied in the course of this investigation.

Spectrograms of early-type stars in the far ultraviolet have led to the discovery of several new very sharp interstellar lines, four of which have been identified as due to *Ti* II. A very faint line at  $\lambda 4227$  is almost certainly due to *Ca* I, and infrared photographs show an interstellar pair of potassium lines near  $\lambda 7700$ . A few other faint lines in the violet are as yet unidentified, but may perhaps be due to a simplified molecular spectrum. The chief interest attaching to the *Ti* II lines is that they arise from the lowest sublevel in the atom. No lines due to the next sublevel, requiring an excitation of only 0.015 volt, are present. Hence nearly all the atoms must be in the lowest level, and atoms raised above it by the absorption of light must return to it spontaneously—a transition for which no laboratory evidence appears as yet to have been found. Theoretical calculations indicate that under the conditions of interstellar space an atom cannot experience a collision with a neighboring atom oftener than once in seven hours. The resulting upper limit for the mean density of the interstellar gases is about  $10^{-20}$  gr/cc. Other evidence indicates still lower values.

Many other stellar spectroscopic investigations have been completed or have made extensive progress during the past year. Among these are spectrophotometric measurements of high-dispersion spectra of seven of the brighter stars, a series of observations of the recent eclipse of  $\zeta$  Aurigæ, a



study of line-intensities in RR Lyræ and  $\alpha$  Cygni, the velocity-curves of numerous variable and binary stars, and infrared observations of late-type stars.

Observations over an interval of 27 years of the rate of expansion of the opposite segments of the large ring nebula in Cygnus, NGC 6960 and 6992, give a value of about 0'06 annually. If the expansion has been uniform, 150,000 years have been required for the ring to reach its present dimensions.

Photographs by Duncan confirm the existence of the faint outer envelope surrounding the Ring Nebula in Lyra, discovered by him in 1935, and show a similar envelope 110" in diameter about the planetary nebula NGC 6826. Eight other planetaries have been examined with negative results. Observations of several planetaries made with the interference spectrograph indicate internal motions considerably more complicated than those predicted from simple assumptions of expansion and rotation.

The use of high-speed red-sensitive plates in the photography of regions affected by obscuring matter has led to most interesting results. Spectrophotometric measures of early-type stars in the central part of the Orion Nebula indicate selective absorption by particles with diameters of the order of 150 m $\mu$ . In the Milky Way heavily obscured globular clusters like NGC 6553, which on blue-sensitive plates show but few stars, are found to be extremely rich in stars on the red-sensitive emulsions. In several cases this high color excess is shared by the surrounding star fields, a result which suggests that much of the effect must be due to relatively near-by clouds. Photographs of the region near the galactic center indicate that strong reddening affects practically all of the partially obscured Milky Way star clouds.

As an aid to the study of the classification and structure of extragalactic nebulae, an index of all catalogued nebulae appearing on Mount Wilson plates has been completed. It includes data on about 1500 NGC objects and 500 of the brighter objects in the *Index Catalogues*.

The photometric study of the neighboring extragalactic system IC 1613 has been nearly completed. This has involved a determination of the color equation introduced in 1935 when the silver coats of the telescope mirrors were replaced by aluminium. The period-luminosity curve in IC 1613 has been extended to periods of about 4 days.

Photoelectric measures of 165 extragalactic nebulae by Stebbins and Whitford show that nebulae of Hubble's types E, Sa, and Sb are nearly uniform in color, while those of type Sc are more varied. Selective absorption within the nebulae is suggested by the results, but none in internebular space. Observations of colors of nebulae, globular clusters, and B-type stars indicate that the ratio of selective to total space absorption within the galactic system is smaller in high than in low latitudes.

Thirty-four extragalactic nebulae have been observed during the year for apparent radial velocity and spectral type. Six of these are in the Virgo cluster and have velocities within the limits previously observed in this cluster. Several spectrograms of the Andromeda Nebula have been obtained with the relatively high dispersion of the interferometer spectrograph. The rotation of two nebulae has been observed spectroscopically. In NGC 3115, in which the luminosity falls smoothly from the nucleus outward, the rota-

tion follows a linear law to a distance of  $\pm 45''$ , which is the limit of the observations. In NGC 4111, however, the rotation, after remaining linear over a central lens with a major diameter of  $12''$ , decreases with increasing distance up to  $50''$  in such a way as to suggest the operation of an inverse quadratic law. The luminosity-curve along the major axis shows two flat sections, one at about  $10''$  and the other at about  $35''$  from the nucleus, which probably indicate the positions of spiral arms.

The distribution in depth of about 100,000 nebulae surveyed by Hubble is closely a uniform, large-scale distribution, provided the apparent magnitudes are corrected by quantities which are linear functions of distance. These corrections are attributed solely to the dimming effects of red shifts in order to avoid a symmetrically increasing density outward. The laws of distribution and of red shift then provide a provisional test of the theory of expanding universes which obey the relativistic laws of gravitation. Only one model fulfills the requirements, one which is closed, small, and comparatively young. If the red shifts are not attributed to motion, the observable region is thoroughly homogeneous but too small a sample to indicate the nature of the universe as a whole.

In the physical laboratory much progress has been made by Russell and King in the analysis of the spectrum of neutral europium, which should aid greatly in the interpretation of other rare-earth spectra. More than 800 lines out of 1650 have been classified, including a large majority of the stronger ones. Spectrograms of *Eu* I and *Eu* II have been obtained between  $\lambda 2100$  and  $\lambda 10,000$  which add many faint lines to those previously known and improve the temperature classification.

Photometric measures of absorption lines in electric-furnace spectra and determinations of the factors proportional to the number of atoms producing individual spectral lines, the so-called *f*-values, are of the utmost importance in the interpretation of solar and stellar spectrophotometric results. Measures of the *f*-values in the spectrum of *Fe* I, begun last year by A. S. King and R. B. King, have been continued and extended, and results for 227 lines in 66 multiplets of the spectrum of *Ti* I have also been completed.

A table of spark lines of iron in the region  $\lambda 5018$ – $\lambda 7711$  has been completed by King, based upon spectrograms of very powerful discharges through the large laboratory condensers. A comparison with the *Revised Rowland Table* has resulted in the identification of 66 solar lines, either in whole or in part, with spark lines of iron.

Experiments by Anderson on the development of the vacuum spark as a general laboratory source of light for spectroscopic purposes indicate that equally bright sparks can be obtained at all pressures from one atmosphere down to one or two hundredths of a millimeter of mercury. From 5 to 10 sparks with a 1-meter concave grating give a spectrogram of average density.

Several brief laboratory studies have been completed by King, one of which was a spectroscopic analysis of the band spectrum of graphite from the Elden stony meteorite. Comparison with terrestrial graphite gave no evidence of any unusual proportion of the heavy isotope of carbon.

About ten diffraction gratings on speculum surfaces have been ruled dur-

ing the year, two of which were used at the solar eclipse of June 8. Tests with a visual photometer show a concentration up to 40 per cent of the incident monochromatic radiation in the green of the first order. Several improvements, including an accurate temperature control, have been added and many minor errors eliminated. Accurate tests of the driving screw of the smaller machine, however, show that it is warped in such a way as to introduce serious errors into gratings designed for high-dispersion work. This screw will be replaced, and during its construction the machine will be used for rulings upon surfaces of different types of material.

The relationship of the Observatory to the visiting public has been a subject to which much consideration has been given during past years. The completion of the new auditorium and exhibits building has made it possible to present the work of the Observatory in a much more adequate and satisfactory way than heretofore, a circumstance which aids greatly in its effective utilization by the public.

#### STAFF

Dr. George E. Hale, Honorary Director of the Observatory since 1923, retired from the staff and was appointed Research Associate of the Carnegie Institution of Washington on July 1, 1936. As his health has permitted, he has been engaged in solar research, including measurements of the general magnetic field of the sun and observations of solar phenomena. Dr. Walter S. Adams, Director, has continued investigations in stellar spectroscopy, together with the administrative duties of the Observatory. Dr. Frederick H. Seares, Assistant Director, has aided in the administration, and, in addition to stellar photometric researches, has continued his editorial supervision of the Observatory publications.

Dr. Arthur S. King, Superintendent of the Physical Laboratory, has been engaged in spectroscopic investigations of rare earths and other elements in laboratory sources and in measurements of multiplet line-intensities. Dr. John A. Anderson has devoted his time to problems connected with the construction of the 200-inch telescope and to laboratory investigations. Dr. Edwin Hubble has continued his studies of nebular distribution and of the cosmological implications of the resulting data and of spectroscopic red shifts. Dr. Walter Baade has been engaged in photometric investigations of star clouds and open clusters and in a survey of partially obscured areas in the Milky Way in light of different colors, with results of great interest. Dr. Paul W. Merrill, Dr. Roscoe F. Sanford, and Dr. Olin C. Wilson have collaborated in an extensive investigation of the intensity and character of the interstellar lines of sodium and calcium in the spectra of a large number of stars and have taken part in numerous other stellar spectroscopic researches. Dr. Seth B. Nicholson has continued in immediate charge of the many types of solar investigations made possible by the present active state of the sun. Mr. Harold D. Babcock is completing his table of the infrared solar spectrum and is superintending the tests and the operation of the ruling machines. Professor Alfred H. Joy, Secretary of the Observatory, has brought to a conclusion his study of the spectra of nearly 200 Cepheid variables and is preparing the material for publication. Dr. Francis G. Pease has divided his time between observations with the stellar interferometers



and features of the design of the 200-inch telescope. Dr. Adriaan van Maanen has carried on further measurements of the proper motions and the parallaxes of selected stars. Dr. Theodore Dunham Jr. has continued observations with the coudé spectrographs and studies of the design of spectroscopic instruments. He observed the total eclipse of the sun on June 8 as a member of the expedition sponsored by the National Geographic Society and the U. S. Navy. Mr. Milton L. Humason has been engaged in further spectrographic observations of the radial velocities and the rotation of extragalactic nebulae and the spectra of faint stars. Dr. Gustaf Strömberg has continued his statistical investigations of the absolute magnitudes of stars and has made observations of the radial velocities of stars in the Selected Areas. Mr. Ferdinand Ellerman carried on solar observations on Mount Wilson and much of the general photographic work of the Observatory until his retirement on June 1, 1937. Mr. Ellerman has been a member of the staff since the establishment of the Observatory in 1904. Dr. Robert S. Richardson has also been engaged in solar investigations, giving especial study to solar eruptions and their relationship to terrestrial phenomena. Dr. Rudolf Minkowski has continued observations with his spectrograph of special design on interference fringes of lines in the spectra of nebulae and on the spectra of certain selected stars. Dr. Sinclair Smith has carried on observations on Mount Wilson, but has devoted most of his time to problems of design connected with the 200-inch telescope. Mr. William H. Christie has undertaken a systematic photographic survey of the sky with a small camera on the 10-inch refractor and has continued his studies of several spectroscopic binaries. Mr. Joseph Hickox has been the regular solar observer on Mount Wilson and has carried on much additional photographic work. Mr. Edison Hoge was appointed to the staff on June 1.

In the Computing Division Miss Louise Ware has used the microphotometers in studies of the contours and intensities of solar spectrum lines. Mrs. Mulders (Miss Elizabeth E. Sternberg) has continued her preparation and compilation of various data relating to solar activity. Mr. E. F. Adams has taken part in this work, as well as in the measurement and reduction of solar spectra. Dr. Boris Karpov, who had assisted in observations and measurements of proper motions and trigonometric parallaxes, resigned on January 1, 1937. Miss Mary C. Joyner has collaborated with Dr. Seares in his photometric researches. Miss Myrtle L. Richmond has been engaged in measurements and computations connected with ultraviolet solar radiation and other investigations. Miss Cora G. Burwell has measured and reduced many of the spectrograms of early-type stars in the region of the interstellar sodium lines and has aided in the discussion of the material. Miss Ada M. Brayton, Miss Grace P. Wilson, and Miss Louise Lowen have assisted in many phases of the stellar spectroscopic work. Miss Wilson resigned on December 1, 1936, and Miss Lowen, who was appointed on February 1, 1937, has also taken part in computations of proper motions and trigonometric parallaxes. Miss Dorothy J. Carlson has divided her time between studies of the contours of lines in stellar spectra with the microphotometer and the compilation of material relating to observations of extragalactic nebulae. Miss Elizabeth R. Cornwall has aided in the preparation of the catalogue of the infrared



solar spectrum. Dr. R. M. Langer has been part-time assistant at the Solar Laboratory, engaged in measurements of the sun's general magnetic field. Miss Elizabeth Connor, Librarian, has assisted in the editorial work of the Observatory.

Dr. Henry Norris Russell, Research Associate of the Carnegie Institution and Director of the University Observatory, Princeton, spent the months of April and May in Pasadena and carried on an extensive intercomparison of trigonometric and spectroscopic parallaxes and absolute magnitudes for stars of various spectral types. He also continued his analysis of the laboratory spectrum of *Eu I* and *Eu II*. Dr. Joel Stebbins, Research Associate of the Carnegie Institution and Director of the Washburn Observatory, with the aid of Dr. Albert E. Whitford, National Research Fellow, and Dr. G. E. Kron, of the Washburn Observatory, continued during the summer of 1936 his measurements of the radiation of B-type and other stars, extragalactic nebulae, and globular star clusters with the photoelectric amplifier.

Dr. S. A. Mitchell, Director of the Leander McCormick Observatory, assisted by Mr. G. F. W. Mulders, of Utrecht, Holland, was engaged in deriving the intensities of chromospheric emission lines on eclipse spectra of the sun during his visit to Pasadena in July and August 1936. Mr. Mulders has also made during the year numerous standardized photographs of the solar spectrum with the 150-foot tower telescope for use in intensity measurements. Dr. Fred E. Wright, of the Geophysical Laboratory of the Carnegie Institution, with the aid of Hamilton Wright, continued his measurements of the polarized radiation of the moon during the latter part of the summer of 1936. Dr. Frank E. Ross, of the Yerkes Observatory, spent several months of the summer and autumn in Pasadena, engaged in computations and tests of correcting lenses for the reflectors on Mount Wilson and the 200-inch telescope. Dr. John C. Duncan, Director of the Whittin Observatory, made observations with the 60-inch and 100-inch telescopes between June and September 1936. Mr. A. D. Thackeray, Fellow on the Commonwealth Fund, returned to England in November 1936 after a stay of nearly two years at Mount Wilson, where he carried on numerous investigations in photographic photometry of solar and stellar spectrum lines. Dr. C. W. Allen, Hackett Research Student, was at the Observatory between August 1936 and March 1937 and also was engaged in solar microphotometry. Dr. Robert King and Dr. Walter Albertson, both of the Massachusetts Institute of Technology, were occupied with spectroscopic investigations in the physical laboratory during the summer months of 1936. Miss Charlotte E. Moore, of the University Observatory, Princeton, and Miss Dorothy N. Davis, from the Students' Observatory, Berkeley, made brief visits to Pasadena and utilized some of the available material in their studies of solar and stellar spectra. Dr. Walter T. Whitney, of Pomona College, carried on photometric observations of selected stars and star fields during the spring months of 1937 with the 60-inch reflector and the 10-inch photographic telescope.

#### OBSERVING CONDITIONS

Observing conditions throughout the year were slightly below the average owing to a winter season of exceptional cold and precipitation. The minimum temperature of 7° F was the lowest recorded since the establishment

of the official weather station in 1915. The precipitation, 53.35 inches as against a 33-year average of 32.16 inches, was the second highest in the history of the Observatory. The total snowfall was 78.5 inches.

Stellar observations were made on 288 nights, of which 211 were clear throughout and 77 partly cloudy. Solar observations were made on 310 days. The accompanying table shows the distribution of the nights during which observations were made with the 60-inch reflector.

Month	Observations			Month	Observations		
	All night.	Part of night	None		All night	Part of night	None
1936:				1937:			
July.....	22	5	4	January.....	4	13	14
August.....	27	3	1	February.....	12	8	8
September....	25	3	2	March.....	12	9	10
October.....	18	3	10	April.....	20	8	2
November....	14	6	10	May.....	22	6	3
December....	13	6	12	June.....	22	7	1
				Total.....	211	77	77
				Mean 25 years..	204	86	75

### SOLAR RESEARCH

Special investigations have been made on bright chromospheric eruptions; on intensities and contours of lines in the solar spectrum at different distances from the center of the solar disk; the wave-lengths, intensities, and identifications of lines in the infrared solar spectrum; the photometry of sun-spots; the infrared spectrum of sun-spots; the motions of prominences; the ultraviolet spectrum of the sun; the possible identification of faint solar lines; on the telluric lines in the spectra of high and low sun; the chromosphere and corona, observed at Canton Island during the total eclipse of June 8.

The routine program of daily observations of sun-spots, prominences, and flocculi and the daily records of the intensity of ultraviolet radiation and of the direction and horizontal intensity of the earth's magnetic field have been continued.

The positions and areas of sun-spots on 64 days from July 1936 to March 1937 were supplied to the Naval Observatory for publication in the *Monthly Weather Review*, and since March 1937, 19 solar photographs have been sent to the Naval Observatory for measurement there. Reports of the daily number of sun-spots and groups have been communicated weekly to Science Service at Washington for publication in their bulletins of *Cosmic Data*. Duplicate spectroheliograms have been supplied regularly to the Kodaikanal and Meudon observatories as a part of the plan of cooperative solar observation. The approximate positions, field strengths, and magnetic classification of all sun-spots have been published regularly in the *Publications of the Astronomical Society of the Pacific*. Estimates of daily character figures of solar activity from calcium and hydrogen flocculi have been sent to Commission 10 of the I. A. U. for publication in its *Bulletin for Character Figures of Solar Phenomena*. These estimates have also been published in *Terrestrial Magne-*

tism and Atmospheric Electricity. The data were compiled and prepared for publication by Nicholson and Mrs. Mulders.

The positions and intensities of bright chromospheric eruptions have been communicated by Richardson to Commission 11 of the I. A. U. for publication in the *Bulletin for Character Figures* as a part of the cooperative program of solar observation with the spectrohelioscope.

Measurements of ultraviolet radiation by Pettit and Miss Richmond have also been published regularly in this *Bulletin*.

Estimates of the daily magnetic character figures have been made by E. F. Adams for publication in *Terrestrial Magnetism and Atmospheric Electricity*.

SOLAR PHOTOGRAPHY

Solar photographs have been made by Ellerman, Hickox, Hoge, Nicholson, and Richardson on 282 days at the 60-foot tower telescope. Direct solar photographs are usually taken early in the morning and followed by spectroheliograms made at the 60-foot focus, the 18-foot focus, and the 7-foot focus, depending on the quality of the seeing. The spectroheliograms with the 7-foot focus objective are on motion-picture film used in an automatic recorder, which is easily exchangeable with the plate-holders and runs continuously unless larger spectroheliograms are being made or the spectrohelioscope is in use for other purposes. The exposures are from one to two minutes duration separated by intervals of from one to two minutes; and within these limits the sun was under observation for an average of 6.5 hours on 282 days during the year. The approximate number of exposures of each kind was as follows:

Direct photographs.....	564
H $\alpha$ spectroheliograms of spot-groups, 60-foot focus.....	370
H $\alpha$ spectroheliograms, 18-foot focus.....	1,400
H $\alpha$ spectroheliograms, 7-foot focus.....	26,000
K2 spectroheliograms, 18-foot focus.....	810
K prominences, 18-foot focus.....	930

SUN-SPOT ACTIVITY

During the calendar year 1936, solar observations were made on 310 days, on all of which spots were visible. The monthly means of the number of groups observed daily during the past two and one-half years are given in the following table.

Month	Daily number			Month	Daily number	
	1935	1936	1937		1935	1936
January.....	1.8	5.6	10.7	July.....	3.0	5.4
February.....	2.3	7.7	12.0	August.....	3.2	7.3
March.....	2.2	7.9	9.5	September.....	4.7	8.1
April.....	1.2	8.4	8.3	October.....	6.6	8.2
May.....	2.6	6.3	8.6	November.....	5.9	8.8
June.....	4.1	7.1	9.8	December.....	6.2	11.2
				Yearly average....	3.6	7.7

The mean number of groups observed daily in February 1937, namely 12.0, exceeded that in any month of the last two cycles. The number of groups in the northern hemisphere belonging to the present cycle increased from 99 in 1935 to 226 in 1936; in the southern hemisphere, from 116 to 233. The total number of groups (459) observed here in 1936 exceeded the number observed in the maximum years of the last two cycles, 450 in 1917 and 424 in 1927. The next maximum is not expected before the end of 1937, and the present cycle will therefore probably be more active than either of the last two cycles. The mean latitude of the spot-zones was  $22^{\circ}7$ .

#### SUN-SPOT POLARITIES

When possible, the magnetic polarities in each spot-group have been observed at least once. The accompanying table indicates the number of spot-groups classified from July 1936 to July 1937. "Regular" groups in the northern hemisphere are those in which the preceding spot has N (north-seeking) polarity and the following spot S polarity. In the southern hemisphere the polarities are reversed.

Hemisphere	Polarity		
	Regular	Irregular	Unclassified
North.....	180	4	79
South.....	166	2	56
Whole sun.....	346	6	135

Since 1840 the solar cycles have had alternately high and low maxima, and since 1908 the distribution of magnetic polarities in sun-spot groups has been observed to reverse at each minimum. The polarity of the general magnetic field of the sun has been observed to be like that of the earth and apparently does not change with the cycle. We may therefore generalize by saying that sun-spots are more numerous in those cycles for which the polarity of the preceding members of bipolar groups is opposite to that of the magnetic pole in the hemisphere in which they occur.

#### SUN-SPOT AND SOLAR SPECTRA

Nicholson has photographed the sun-spot spectrum from  $\lambda 8300$  to  $\lambda 8850$  with the 75-foot spectrograph at the 150-foot tower telescope through polarizing apparatus suitable for the study of Zeeman displacements. Many new spot lines are recorded on these spectrograms, and an interesting group of unidentified lines near  $\lambda 8715$ , probably of molecular origin, appears to have reversed Zeeman patterns, with separations from one-fourth to one-third those of atomic lines in the same region.

An earlier search by Richardson for possible lines due to molecular hydrogen  $H_2$  in sun-spot spectra has now been extended by him to the solar spectrum, in which they might be more likely to appear because of high



excitation potential. No satisfactory evidence has been found of their occurrence in the spectrum of the sun's disk.

#### DISTRIBUTION OF CHROMOSPHERIC RADIATION OVER THE SOLAR DISK

The relative intensities of  $H\beta$ ,  $H2$ , and  $K2$  were measured across the solar disk by Pettit and compared with similar measurements in the near-by continuous spectrum of the photosphere. These measures were made on drift curves across a 2.5-inch solar image, with a photocell placed directly in the spectrum formed by a concave grating of 21.5 feet radius. The falling off in radiation toward the limb in both hydrogen and ionized calcium is less than in the near-by continuous spectrum, 7 per cent less for hydrogen and 25 per cent less for calcium.

#### BRIGHT CHROMOSPHERIC ERUPTIONS

Richardson has continued the study of bright chromospheric eruptions and finds that their effectiveness in producing radio fade-outs depends primarily on their intensity and is independent of their position on the solar disk. The evidence at present indicates that the energy producing the fade-outs is probably line emission in the far ultraviolet.

Bright chromospheric eruptions generally, although not always, occur near an active spot-group and develop with great rapidity, reaching maximum brightness in a few minutes and then fading much more slowly, sometimes over a period of several hours. The bright material is at a high level in the solar atmosphere, higher than the ordinary chromospheric level, and the intensity of the radiation in  $H\alpha$  may exceed twice that in the adjoining continuous spectrum. The bright eruptive flocculi are visible in the  $H$  and  $K$  lines of ionized calcium, as well as in the Balmer series. They have also been observed in the infrared lines of ionized calcium and in other strong metallic lines. Their areas are not large, never more than a few per cent and usually less than one per cent of the solar surface.

#### MOTIONS OF PROMINENCES

At the invitation of Director Robert R. McMath, Pettit spent the months of July and August at the McMath-Hulbert Observatory of the University of Michigan, studying prominence motions by the motion-picture method with the recently completed tower telescope and spectroheliokinematograph. Observations were made in collaboration with Mr. McMath on 43 days, and a total of 2000 feet of film was obtained, mostly with a focal length of 40 feet, but sometimes with 18 feet, on occasions when the image of the prominence became too large. Effort was concentrated on prominences of the sunspot and active types. The films were measured on a machine constructed at Mount Wilson. The frequency of exposures, generally of the order of 25 to 45 seconds, permitted detailed studies of prominence motions not hitherto available. For example, for the plot of the motions of streamers and knots in the class IIIa prominence of August 22, 75 positions were secured in 29 minutes, detailing the motion over a distance of 200,000 km.

Sometimes complete loops appear, rising from and returning to the spot area like a fountain. The loops may rise to great heights, nearly reaching

the eruptive stage before returning to the center of attraction. Eruptive prominences are probably extreme cases in which the trajectory becomes a tall, narrow loop, and the prominence fades out before completing its trajectory.

The chromosphere is in continual motion, rising and falling like surf on the coast line. Occasionally a mass will burst through the chromosphere, rise, and sink back. Such prominences have been called surges and, when abnormally bright, are the bright chromospheric eruptions associated with radio fade-outs. One of these observed on August 8, 1936, rose to a height of 80,000 km with a velocity of 240 km/sec; it was 50 per cent brighter than the chromosphere and coincided with a radio fade-out. Its form was apparently the same in  $H\alpha$  and in K2, throughout its life of only about one hour.

#### INTENSITIES OF FRAUNHOFER LINES

C. W. Allen, Hackett Research Student from the University of Western Australia, measured the contours of lines in the atmospheric oxygen bands A, B, and  $\alpha$ . The values of one-half the collision breadth corresponding to the absorption coefficient at normal pressure for these bands were found to be 0.047, 0.049, and  $0.050 \text{ cm}^{-1}$ , respectively. The resulting effective collision diameter of  $O_2$  in air was  $4.2 \times 10^{-8} \text{ cm}$ , and the absorption coefficients of the bands A and  $\alpha$  relative to B were 13.5 and 0.039, respectively.

The study of the oxygen lines gave corrections for the resolving power of the spectrograph, which were used in obtaining the central intensities and equivalent breadths of 91 solar lines in the spectral regions near the oxygen bands. The lines were found to be wider than theory predicts, unless the sun's reversing layer is subject to turbulent velocities of the order of 1.6 km/sec.

G. F. W. Mulders photographed the solar spectrum from  $\lambda 3800$  to  $\lambda 6900$  in the second order of the 75-foot spectrograph, and from  $\lambda 6600$  to  $\lambda 8900$  in the first order, on plates calibrated photoelectrically. The plates were obtained for the University of Utrecht, where they are now being measured and reduced. Mulders also studied the intensity of the ghosts of the neon emission line  $\lambda 5856$  and found them to be 1 per cent of the principal line in the first order and 4 per cent in the second order of Michelson's grating No. 66.

Nicholson and Miss Ware have measured the effective breadth and sharpness of 340 solar lines in the spectrum at the center of the solar disk and at the limb between  $\lambda 5400$  and  $\lambda 5900$ , ranging in Rowland intensity from  $-1$  to 8.

#### SPECTRAL DISTRIBUTION OF SOLAR ENERGY FROM $\lambda 3500$ TO $\lambda 5000$

The absorption produced by the Fraunhofer lines in the solar spectrum was measured by Pettit for each 100 Å between  $\lambda 3500$  and  $\lambda 5000$ . It was found that the observed energy-curve of the sun, including the Fraunhofer lines, must be multiplied by factors varying from 1.15 near  $H\beta$  to 1.64 near H and K to correct it for line absorption.

#### ULTRAVIOLET SOLAR RADIATION

Pettit has repeated the thermoelectric measurements of the ultraviolet spectral energy-curve, using improved instrumental equipment. The previ-

ous measurements were verified, showing that the radiation outside the atmosphere in the interval  $\lambda 0.38\mu$  to  $\lambda 0.325\mu$  does not vary appreciably with wave-length and is somewhat less than one-half the maximum intensity at  $\lambda 0.48\mu$ .

#### INFRARED SPECTRUM OF DISK

Babcock has continued his investigation of the infrared spectrum of the disk. Weak solar lines have been segregated from those of terrestrial origin; line-intensities have been estimated visually; preliminary wave-lengths have been derived for several hundred new faint lines near the beginning of the *Mount Wilson Infrared Table*; and a few interesting identifications have been made. The presence of the fundamental series of sodium lines has been established in the sun by comparison with improved laboratory data obtained by Sawyer. The first member of the principal series of lithium,  $\lambda 6707$ , long recognized in the spot spectrum, has now been found in the spectrum of the disk. Although weak and diffuse, it corresponds so closely in position and in fine structure with the laboratory line as to leave little doubt of the identity.

#### ABSORPTION SPECTRUM OF WATER VAPOR

In preparing the wave-length table for the infrared spectrum, certain water-vapor lines are necessarily included because they affect the visibility of some of the solar lines. The stronger telluric lines are usually too greatly blended to permit accurate measurement and, unless essential, the weaker ones have not been entered. New observations of some of the less prominent telluric lines have, however, considerable interest. About 200 peculiar atmospheric lines measured in the orange and red are so diffuse that they might easily be mistaken for solar lines if they did not nearly all disappear an hour after sunrise, whereas ordinary telluric lines weaken much more gradually. Babcock has identified about 20 of these lines near  $\lambda 6300$  with water vapor, and it seems probable that many more can be assigned to this source. Although it now seems certain for the first time that a weak band of water vapor is superposed on the  $\alpha$ -band of oxygen, its peculiarities remain to be explained. Possibly the phenomenon of pre-dissociation is involved here.

Another telluric band,  $\lambda \lambda 5600-5800$ , has been examined visually under many conditions, and some of its individual lines have been studied on high-dispersion spectrograms. These lines also are diffuse, but they vary in strength in a manner wholly different from that of water vapor or oxygen. This band is superposed on a very weak oxygen band, but is so much stronger at times that it completely obscures the oxygen band. Ångström long ago concluded that it is not due to water vapor. The present work indicates that while it may have some connection with the  $H_2O$  molecule, it is certainly not due to water vapor in the physical state involved in the well-established infrared bands.

Visual observation has confirmed the existence of a faint band discovered by Ångström near  $\lambda 5035$ , but his assignment of it to water vapor is not certain. High-dispersion spectrograms failed to show any detail either here or near  $\lambda 4800$  where he reported another atmospheric band.



## SPECTRUM OF MOLECULAR OXYGEN

Because of their comparatively simple structure, the oxygen bands present on our solar spectrograms can profitably be treated differently from those of water vapor. Every possible line of oxygen is being measured and assigned to its place in the system of bands, the total now being about 575. During the year two new bands of ordinary oxygen,  $O^{16}O^{16}$ , near  $\lambda 6970$  and  $\lambda 6370$ , respectively, have been predicted and identified by Babcock. A further band in the green remains to be sought and analyzed before closing this investigation.

Precise wave-lengths of some of the lines of atmospheric oxygen have been used to determine the internuclear distance in oxygen molecules. The results indicate a slight reduction of internuclear distance in the isotopic molecule,  $O^{16}O^{18}$ , relative to the ordinary molecule in the excited state but not in the normal state. The application of powerful instruments to these sharp lines has given a new order of accuracy for differential observations of internuclear distance.

## MEASUREMENT OF SOLAR TEMPERATURE

An application of the laboratory  $f$ -values to the determination of the temperature of the sun's reversing layer has been made by R. B. King, now of the Massachusetts Institute of Technology. The  $f$ -values of  $Ti I$  lines were compared with the equivalent widths of the corresponding solar lines measured by C. W. Allen. The determination of Boltzmann factors for lines arising from different atomic energy levels then led to a mean temperature of  $4400^\circ \pm 100^\circ$  K for the level in the solar atmosphere at which these titanium lines are absorbed most effectively. With the aid of this temperature and the laboratory  $f$ -values, an empirical curve of growth could then be constructed for the solar lines of iron and titanium.

## SOLAR ECLIPSE OF JUNE 8, 1937

At the invitation of Dr. S. A. Mitchell and the National Geographic Society, the Observatory took part, with Dunham as its representative, in the eclipse expedition to Canton Island in the Pacific Ocean sponsored by the National Geographic Society and the U. S. Navy. A spectrograph embodying a 32-inch Schmidt camera was set up and used, with a new very bright grating ruled by Babcock, to photograph the spectrum of the corona on plates and the chromospheric spectrum, at closely spaced intervals, on motion-picture film. The eclipse was observed under ideal conditions and, while it was not possible, under the conditions available, to operate the motion-picture spectrograph as planned, several flash spectra of good quality were obtained. The spectrum of the corona shows at least one line not previously recognized.

## SOLAR PARALLAX

The accuracy with which the wave-lengths of emission lines can be determined with the interference spectrograph has led to an attempt by Minkowski to derive the solar parallax from a series of observations of the  $H\alpha$  line in Messier 8. The nebula is very close to the ecliptic and seems to be comparatively free from turbulent internal motions.



## LUNAR AND PLANETARY INVESTIGATIONS

### SURFACE FEATURES OF THE MOON

Dr. F. E. Wright, Chairman of the Committee on Study of the Surface Features of the Moon, has continued his measurements of the percentage amount of plane polarization produced in light reflected and diffracted by terrestrial and lunar surface materials. The relative intensity of polarization thus introduced depends on the angle between the incident and the diffracted beams of light (phase angle) and on the nature of the scattering material and its surface. On the basis of the data on polarization obtained on terrestrial materials, it is possible to separate them into groups and to compare their characteristics with those obtained for different areas on the moon. Visual measurements of plane polarization have been made on a large number of terrestrial substances; the results obtained are in accord with the conclusion drawn some years ago that the surface materials of the moon are of the nature of volcanic ashes and pumice high in silica content.

Study of the shapes and sizes of lunar surface features has been made on a series of photographs of the moon's surface by observation of the angle of grazing incidence of the sun's rays on a given slope. This study is of a preliminary character, preparatory to a more detailed study of a series of photographs to be taken with the 100-inch telescope throughout an entire lunation. The new zero-corrector lens in course of construction for the Newtonian focus of the 100-inch telescope will be used for this purpose.

A new set of lunar photographs, projected on glass globes 13.75 inches in diameter, has been completed. These angle-true representations of the moon are of great help in study of the physiography of the lunar surface.

### PLANETARY PHOTOGRAPHY

The coudé focus of the 100-inch reflector offers certain advantages in photographing planets. The scale of planetary images at a focal length of 250 feet is such that no auxiliary enlarging lens is required. A number of photographs of Mars, Jupiter, and Saturn have been made by Dunham on motion-picture film, using in the focal plane a Leica camera without lens. Recent experiments with Kodachrome film have yielded interesting photographs of the planets in color, which have the further advantage that the grain of the emulsion is negligible.

### WATER VAPOR IN THE SPECTRUM OF MARS

Observations of the spectrum of Mars in the region near  $\lambda 7200$ , where numerous strong water-vapor lines appear in the spectrum of the earth's atmosphere, were made by Adams and Dunham shortly before the recent opposition. The first order of the plane-grating spectrograph was used at a focal length of 9 feet, which gives a linear scale of 6 Å per mm. Eastman III N plates, hypersensitized with ammonia, were found most suitable.

The first observations were made in February when the planet had a velocity of approach of 19 km/sec, corresponding to a displacement of 0.45 Å. This should completely separate Martian from terrestrial water-vapor lines, but studies of the original negatives and of large-scale microphotometer tracings gave no evidence whatsoever of the presence of a Martian component.

In April a spectrogram was obtained at a time when the velocity of the planet was less, and any Martian lines should appear as fringes on the edges of the terrestrial lines. This spectrogram was measured but the resulting wave-lengths agreed in the mean within 0.001 Å with those measured by Babcock in the solar spectrum.

The conclusion is that at the center of the disk of Mars at this time (the polar caps were not satisfactorily observable) there was no evidence for the existence of sufficient water vapor to be detectable on these high-dispersion spectrograms. An estimate based upon measures of the microphotometer tracings and comparisons with solar spectra at different altitudes of the sun would place an upper limit of about 5 per cent for the possible intensity of Martian as compared with terrestrial lines. Probably the ratio is considerably less.

## MISCELLANEOUS STELLAR INVESTIGATIONS

### TRIGONOMETRIC PARALLAXES

Among the stars for which van Maanen has derived trigonometric parallaxes the large majority are faint stars of large proper motion. Eight of these are found to have photographic absolute magnitudes fainter than +10; in the case of Ross 508 and the companion of Lalande 38380 the magnitudes are +15.1 and +15.4, respectively.

For the white dwarf BD +70°8247, the absolute parallax measured by van Maanen is +0".048; a mean of this value and +0".066 obtained by the Greenwich observers gives an absolute magnitude of +11.5.

The absolute parallax of the variable star U Geminorum is found to be +0".010 ± 0".007. Although this value is too small to permit of very definite conclusions, it indicates a visual absolute magnitude of the order of +4.5 at maximum and +8.5 at minimum of light.

### PROPER MOTIONS

The program of duplicating the earlier photographs of stars with large proper motions has been practically completed by van Maanen. In the 222 fields, each covering about one-quarter of a square degree, 100 stars have been found which show proper motions exceeding 0".050 per year. There are only two stars with a motion exceeding 0".5 which are not companions of the central stars, also of large motion. The 17 new companions found in this investigation have distances from the central star ranging from 2" to 738"; their photographic absolute magnitudes range from +10.2 to +14.7.

Proper motions of the stars in Selected Area 35 have been measured for the purpose of learning what accuracy can be expected for the motions of very faint stars through duplication of some of the oldest photographs taken at the primary focus of the 60-inch reflector. For this area one old photograph, a Sigma Lumière plate with an exposure of 1 hour, and two Seed plates of 15 minutes each are available. The interval for the 1-hour exposure was 21 years, for the 15-minute exposures, 24 years. The probable errors in the final motions are 0".004, in each coordinate, for the first, and 0".002 for the latter. The long exposure on the Lumière plate, however,

shows a considerable magnitude error for stars brighter than 15. The loss in magnitude on the shorter exposures is relatively small, about 0.3 magnitude; the loss in magnitude, therefore, seems to be well balanced by the increase in accuracy.

A further step in van Maanen's investigation of the frequencies of intrinsically faint stars has been gained through the derivation of the frequency distribution at different distances from the sun. In the first discussion the material used consisted of stars whose proper motions exceed 0".5 annually. Of the 735 stars with motions between 0".3 and 0".5 for which parallaxes are known at present, only very few, perhaps 5 per cent of the total number, have parallaxes exceeding 0".158. Hence when stars having motions greater than 0".5 are used, the data for stars with parallaxes exceeding 0".158 will be practically complete. It is thus found that in our immediate neighborhood the maximum frequency is at absolute magnitude  $+12.7$  and the density is about 1 star per 5 cubic parsecs. The result could be extended to larger distances if we knew the distribution of the proper motions of still fainter stars, and for this reason a beginning has been made on the measurement of the motions of stars in the Selected Areas to a limit about 3 magnitudes fainter than those measured hitherto.

#### PHOTOMETRIC EXTENSION OF THE POLAR SEQUENCE

Work on the magnitudes of stars north of  $80^\circ$ , undertaken jointly with Dr. Ross, of the Yerkes Observatory, as a supplement to the standards of the Polar Sequence, has been continued by Seares and Miss Joyner. As already reported, the photographic magnitudes, mostly brighter than 11.5, have been finished, and the reduction of much of the photovisual material is complete. Difficulties with irregular plate corrections affecting some of the fields suggested the desirability of an additional series of photographs, centered at  $85^\circ$ , as a means of strengthening the connection between the series at  $83^\circ$  and  $87^\circ$ . All but one of the six pairs of new plates have been measured and partially reduced.

#### PHOTOELECTRIC MAGNITUDES OF THE NORTH POLAR SEQUENCE

With the 60-inch reflector Stebbins and Whitford have measured the photoelectric magnitudes and colors of the 30 brightest stars of the North Polar Sequence. Laboratory tests at Mount Wilson and independent observations of the same stars with the 15-inch telescope at Madison show that the photoelectric scale is correct to 0.01 or 0.02 mag. over a range of 9 magnitudes. Comparison with the standard magnitudes of the international system has revealed unexpected systematic discrepancies of 0.1 mag. or more.

An investigation by Seares shows that a modification of the reduction for differences in color sensitivity underlying the two systems of magnitudes removes all the important systematic differences between the sixth and the eleventh magnitudes. The residual accidental difference for this interval is  $\pm 0.017$  mag. The remaining discordance of about 0.1 mag. affecting stars 1 to 4 is attributed by him chiefly to the influence of hydrogen absorption, which is conspicuous in the early A stars and influences the photographic magnitudes but has little effect on the photoelectric measures.



## FAINT PHOTOMETRIC STANDARDS IN SELECTED AREAS

Continued experiments by Baade as to the best method of determining faint photometric standards with the 100-inch reflector leave no doubt that the platinum half-filter gives the most satisfactory results. It has the very important advantage over all other methods tried here that the exposures for the filtered and unfiltered images are simultaneous, which eliminates the troublesome effects of varying seeing. A platinum half-filter with an absorption constant of about 1.5 mag., made by Dr. Strong, of the California Institute of Technology, is now being used for a final check of the standards between magnitudes 17 and 21 in Selected Area 68.

## COLORS OF B-TYPE STARS

Stebbins and Whitford have continued their photoelectric survey of the colors of faint B-type stars in selected regions near the direction of the galactic center. Practically all B stars in the bright clouds of Sagittarius show measurable color excess, thus indicating that even the brightest parts of the Milky Way are partially obscured by a thin veil of dark matter in interstellar space.

## STELLAR LUMINOSITIES

Strömberg has developed a method for determining the distribution of intrinsic stellar luminosities by grouping stars according to their reduced total proper motions  $H$  ( $H = m + 5 \log \mu$ ), and for each group determining the mean absolute magnitude and the dispersion in magnitude from trigonometric parallaxes. The study so far has been limited to stars of spectral types G8-K2. The relation between  $H$  and  $M$  shows immediately the clear distinction between supergiants, normal giants, subgiants, and dwarfs. This evidence is important, since it is independent of the relative proportion of these classes of stars in the group under investigation.

The distribution of absolute magnitudes can also be determined by this method. Although it cannot give all the details of the distribution-curve as distinctly as do some other methods, the results are more definite and are found to be in very good agreement with those based upon a comparison of the distribution of proper motions with that of radial velocities.

## TRIGONOMETRIC AND SPECTROSCOPIC PARALLAXES

Russell has been engaged in a comparison of the Mount Wilson spectroscopic parallaxes (*Contribution* No. 511) with the trigonometric parallaxes of Schlesinger's *Yale Catalogue*. The calibration curves used in deriving spectroscopic absolute magnitudes and parallaxes are necessarily based on the mean values derived by other methods for groups of stars for which the spectroscopic criteria are substantially the same. The determination of the latter is affected by accidental errors of observation, and probably by physical peculiarities of individual stars. It follows that the calibration curves must be of the nature of regression curves, and thus indicate smaller differences in absolute magnitude between groups with the same mean spectral criteria than would be obtained if the grouping could be made in some impartial way which did not tend to select cases in which the accidental errors were predominantly of one sign.



The amount of this influence can be determined by methods resembling those used in the study of correlation. A weighting system is necessary on account of the great differences in the accuracy of the trigonometric parallaxes and of the wide dispersion in the distances of the stars.

Ample material is available—more than 1100 stars of the main sequence and 700 giants. The stars were grouped in narrow spectral subdivisions, but it was found that these could be widened without loss of accuracy.

The results indicate a very satisfactory degree of reliability in both the trigonometric and the spectroscopic parallaxes. The differences in zero point for the two systems are very small, and negligible for most spectral classes. The calibration can be slightly improved by increasing the differences between the absolute magnitudes given in *Contribution No. 511* and the mean values for each spectral subclass by 7 per cent for the giants and 16 per cent for stars of the main sequence.

The size of the accidental errors of the spectroscopic determinations, which appear to be larger than previously supposed, is still under investigation.

#### STELLAR INTERFEROMETER

The following measures of stellar diameters have been made by Pease with the 50-foot interferometer. The separation of the mirrors for zero visibility of the fringes is given in the second column.

Star	Separation of mirrors	Angular diameter
$\beta$ Andromedæ .....	44 feet	0".0108
$\alpha$ Ceti .....	51	0.0094
$\alpha$ Orionis .....	14	0.034
$\alpha$ Scorpii .....	17	0.028

The spectroscopic binary  $\beta$  Capricorni was also observed, but no evidence of duplicity was found at a separation of the mirrors of 40 feet where the visibility of the fringes was still 80 per cent.

#### AN AUTOMATIC GUIDING DEVICE

Whitford and Kron have tested upon the 60-inch telescope the performance of an automatic device for holding a star in a fixed position upon a photographic plate, which they had previously developed at the Washburn Observatory of the University of Wisconsin. The device was found to work satisfactorily on stars as faint as magnitude 8.6. The photosensitive part of the mechanism was a Zworykin electron multiplier. Further improvements to enable the instrument to operate on fainter stars will depend upon a better signal-to-noise ratio in the output from the original photosensitive cathode and its associated amplifier. The mechanical problems appear to be solved satisfactorily.

#### POSITION OF NOVA LACERTÆ 1936

Nova Lacertæ 1936 was photographed by Duncan during the summer of 1936 with exposures of as much as 2 hours with the 100-inch telescope. No evidence of nebulosity around the star was detected. The position of the nova, as determined by the aid of 6 comparison stars chosen from the *Astrophysical Catalogue* and referred to the equinox of 1900, was found to be:

$$\alpha \quad 22^{\text{h}} 12^{\text{m}} 0^{\text{s}}.26 \pm 0^{\text{s}}.018 \quad \delta \quad +55^{\circ} 7' 8''.2 \pm 0''.15$$

## STELLAR SPECTROSCOPY

Use of the plane-grating spectrograph at the coudé focus of the 100-inch telescope has increased greatly during the year, a 9-foot camera lens being used for high-dispersion spectra of the brighter stars and the 32-inch Schmidt camera for stars as faint as photographic magnitude 7.0. The Schmidt camera has proved efficient in the second-order ultraviolet of the large grating, and spectra on fine-grained plates have been photographed as far as  $\lambda 3050$ . The excellent definition and great extent of spectrum in focus on these plates make them of exceptional value. The grating ruled by Professor R. W. Wood on aluminium on glass shows remarkable concentration of light in the yellow and red of the first order, and in the ultraviolet, violet, and blue of the second order. Spectra of the brighter stars have been photographed with the 9-foot camera lens in the second order of the blue and violet, and in the first order of the yellow and red, the linear scale of the spectrograms being about 3.1 and 6.1 Å per millimeter, respectively.

At the 60-inch telescope the 3-prism ultraviolet glass spectrograph has been used extensively, both for general observations of radial velocity and for special studies of the stellar and interstellar H and K lines. Of a total of 1241 stellar spectrograms obtained during the year at the two large reflectors, more than two-thirds were made with the 3-prism and coudé instruments.

## RADIAL VELOCITIES

Measurements of radial velocity have been continued regularly throughout the year, and a catalogue of 600 stars for which determinations have been completed is being prepared for publication. This list includes many stars of the Boss *Preliminary General Catalogue*, dwarf stars of large proper motion, and a number of stars in the Selected Areas which have been under observation by Strömberg.

 $\beta$  CAPRICORNI

This interesting spectroscopic binary, to which reference was made in last year's Report, has been investigated by Sanford. The second component is itself found to be a spectroscopic binary with a period of  $8\frac{2}{3}$  days and minimum masses of its components of 10.3 and 1.8 times the sun's mass. The minimum mass of the principal star of the system is 27.5 times the sun's mass. The period of 1375.3 days found by Merrill many years ago for the long-period binary needs to be slightly shortened.

## CEPHEID VARIABLES

The important investigation by Joy of the spectra of Cepheid variables, which has extended over 17 years and has included 190 stars north of declination  $-40^\circ$ , has been brought to a conclusion, and the results are nearly ready for publication. Only 25 of these stars had been observed previously with the spectrograph; but, with the aid of low dispersion, observations have now been carried to stars of the fourteenth photographic magnitude. More than 1000 spectrograms have been measured for radial velocity, the normal velocity and the range being determined for each star. Velocity-curves have been drawn for 106 stars.

Statistical studies of the data indicate that, while the scatter is considerable, the correlation between period and velocity-range is well marked. The time of maximum velocity of approach occurs somewhat later than that of maximum light, and maximum velocity of recession falls after minimum light. The mean lag is about 7 per cent of the period, the general increase with length of period being well shown. The results will be used to determine the peculiar motions of these stars, their motions with respect to the sun, and the rotation of the galaxy.

Under good observing conditions, the spectra of a few of the brighter Cepheids in globular clusters have been obtained. These include Barnard's Variable (period 15.3 days) in M 3, and Chévremont's Variable (period 33.6 days) in M 2, for which satisfactory radial velocities have been measured.

#### LONG-PERIOD VARIABLES

Several high-dispersion spectrograms of  $\alpha$  Ceti taken with the coude spectrographs have provided the material for a study by Joy of the structure of the hydrogen lines at different phases of the light variation. Many previously unobserved emission lines, due mainly to  $Fe\ I$ , have been found in the region  $\lambda 3600$ – $\lambda 3900$ .

Joy and Merrill have found that the bright hydrogen lines in the spectrum of V Canum Venaticorum (period 195 days, spectrum M4e–M6e) persist throughout the period. Maximum velocity of recession occurs near maximum of light, and, in the mean, the emission lines are displaced to the violet by 6.3 km/sec with reference to the absorption lines.

A possible explanation of the exceptional behavior of the iron lines  $\lambda\lambda 4202$ ,  $4308$  and other emission lines in the spectra of long-period variables has been advanced independently by Thackeray and by Merrill. It depends upon the hypothesis (similar to that offered by Bowen for certain nebular lines) that the atoms are raised to the particular level in question by the chance coincidence of a line from a ground or very low level with a very strong line of some other element. Two astrophysically unobservable lines of  $Mg\ II$ ,  $\lambda 2796$  and  $\lambda 2803$ , would thus provide the exciting radiation for the two iron lines in question, as well as for two other emission lines observed in the spectra of these stars. This should serve as a most useful working hypothesis for further investigations.

#### SPECTRA OF SOME BRIGHT STARS

The coude spectrographs at the 100-inch telescope have made it possible to apply exceptionally high resolving power to the spectra of the brighter stars. The red giants  $\alpha$  Orionis and  $\alpha$  Scorpii are known from previous observations to have marked peculiarities in their spectra, especially as regards the width and character of many of their lines. When photographed in the second order of the 9-foot spectrograph with the large Wood grating, a number of the lines are found to be double, all of them ultimate lines of the neutral or ionized atom. Especially prominent are the  $Mn\ I$  triplet near  $\lambda 4030$ , the  $Sr\ II$  pair  $\lambda 4078$  and  $\lambda 4216$ ,  $Ca\ I\ \lambda 4227$ , and the  $Cr\ I$  triplet,  $\lambda\lambda 4254$ ,  $4275$ ,  $4290$ . Measures by Adams show these double lines to be "reversals," the mean of the two components agreeing closely with the normal position



of the line, but the intensities of the components to be unequal, in nearly all cases the violet being the stronger. It seems probable that this doubling effect is associated with the deep atmospheres of these stars and the distribution of density within them.

Similar observations of the spectrum of  $\alpha$  Cygni show the interstellar H and K lines standing out clearly upon the wings of the broader and more diffuse stellar lines. The displacement of the interstellar with reference to the stellar lines, on May 28, 1937, was 9.8 km/sec to the violet.

The ultraviolet spectra of a number of representative stars of early spectral type (O-F) have been photographed by Adams and Dunham at the coude focus as far as  $\lambda 3050$ , both with the grating spectrograph and 32-inch Schmidt camera and with the 9-foot quartz spectrograph. Many lines of atoms in high states of ionization which have not been observed previously appear on these spectrograms. These lines are being measured for wave-length, and their total intensities are under investigation by Dunham.

#### NOVÆ

Measurements in the visual region of the spectrum of Nova Herculis (1934), published by Merrill in *Contribution* No. 530, have since been supplemented by him by photometric observations of the more important features (*Contribution* No. 563). Equivalent widths and residual intensities of the dark lines of component I are compared with corresponding data for  $\alpha$  Cygni, and the behavior of the various components of the D lines of sodium for several months after the appearance of the nova is exhibited by a series of tracings and a table of intensity measurements. Data on other dark lines are included. The remarkable sequence of changes in the intensity and structure of the emission lines of Fe II and [O I] is described by tracings and tabular data. The relationship of these changes to the magnitude of the nova is discussed briefly, with a hypothetical explanation of certain phenomena.

Observations of the spectrum of Nova Lacertæ (1936) were continued from June 18, 1936, the date of its discovery, until early July, when most of the absorption features had disappeared. Velocity-curves for the three principal absorption components were determined and published by Adams, Sanford, and Wilson. The star was of exceptional interest because of the magnitude of the velocities involved, the rapidity of the changes, and the quality, during a portion of the time, of the principal component, which made possible an accurate determination of the rate of acceleration.

A few observations of the spectrum of Nova Sagittarii (1936) were obtained by Joy, Adams, and Dunham, although the position of the star prevented long exposure times. The spectrum was characterized by emission bands some 60 Å wide which showed several maxima and minima of intensity in their structure. The hydrogen lines H $\delta$ , H $\gamma$ , and H $\beta$  were each represented by two hazy absorption components on the violet side of the emission bands, which gave velocities of -2130 km/sec and -3590 km/sec. The latter is one of the highest velocities ever observed in the case of novæ. The star showed strong interstellar sodium lines which indicate a distance of the order of 2000 parsecs (6500 light-years).



Spectrograms of the two novæ of 1936 in Aquila, 618.1936 (Sept.) and 668.1936 (Oct.), were obtained soon after announcement of their discovery, and observations of most of the novæ of recent years have been repeated by Joy with low dispersion during 1937. These observations have included the stars RS Ophiuchi and RT Serpentis. Humason, using the small-scale nebular spectrograph, has observed 11 old galactic novæ which are characterized by O-type spectra with emission lines.

#### INTERSTELLAR LINES

Since 1924, more than 1000 spectrograms of early-type stars have been obtained by Merrill and Sanford in an extensive investigation of absorption lines due to interstellar matter. Approximately 720 are of the region of the D lines, and 300 are of H and K. Of 404 objects observed, 147 are fainter than apparent magnitude 7.0. All the plates have now been measured and reduced, and the results are ready for publication (*Contribution No. 576*, Merrill, Sanford, Wilson, Burwell). The numbers of objects with the various kinds of data are as follows:

	Ca	Na	$\lambda 6284$
Displacement .....	174	264	...
Intensity: Measured .....	114	213	129
Estimated .....	89	107	...

Intensities of  $\lambda\lambda 5780$  and  $5797$  in numerous stars are included.

Several portions of the general discussion of these results have been completed. Data for double stars bear out the expectation that interstellar lines should behave alike in the spectra of the components of a pair. A regional study of Na has been made by Merrill (*Contribution No. 569*) and of Ca by Sanford (*Contribution No. 573*).

A detailed study of the distance-intensity relationship in 23 areas shows that regional differences, while probably present, are not extremely great. For the sodium lines the mean relationship between intensity,  $y = 0.5(D2 + D1)$ , and  $x =$  distance (corrected for space absorption), is represented to 2000 parsecs by the equation

$$y = 0.00144x^{0.86}.$$

Data for regions chosen with regard to the null points of galactic rotation indicate that the standard galactic rotation plays a relatively minor rôle in producing the observed intensities of detached D lines. On the other hand, in the observed displacements of lines in stars in various longitudes, the influence of galactic rotation is plainly marked.

A study of the intensities of the sodium lines (*Contribution No. 570*, Wilson, Merrill) shows that the ratio of D2 to D1 is about 1.2, except for very weak lines, where it rises to its normal value of 2.0. The observed ratio 1.2 indicates that, if the number of atoms is doubled by matching each atom with a similar additional atom, the line intensity is increased by 20 per cent; on the other hand, if the number of atoms is doubled by extending the light-path twice as far into space, the line intensity is increased by 80 per cent. The properties of sodium gas cannot therefore be identical at all points in interstellar space. Motions corresponding to the standard concept of galac-

tic rotation do not suffice to solve the difficulty. The most reasonable solution appears to be that of discrete clouds of sodium vapor several hundred parsecs across with appreciable random velocities, forming perhaps the gaseous counterpart to the well-known dust clouds of obscuring matter along the Milky Way.

As by-products of this investigation an upper limit (because small-scale turbulence would be included) of  $40,000^\circ$  is found by Wilson for the temperature of the interstellar sodium gas, and a density of about  $10^{-21}$  gr/cc. This investigation, like those already referred to, shows that the rotation of the galaxy cannot be the major source of the widths and total absorptions of the D lines.

A comparison of the measurements of detached H and K with those of the D lines (*Contribution* No. 564, Merrill and Sanford) shows that in types B3 and earlier the displacements are in good general agreement. In types B5 to A2 the results bring out the existence of blending of interstellar with stellar calcium lines. In these types the detached D lines are much freer from interference from stellar lines than are H and K. This fact represents one of the principal advantages of observing the D lines.

The data make it highly probable that throughout the regions under observation the motions of sodium and calcium atoms are, with possible minor exceptions, similar, and that the densities are nearly proportional.

A special investigation by Merrill and Wilson has provided data on the structure and mean wave-lengths of the interstellar lines  $\lambda\lambda 5780.55$ ,  $5797.13$ ,  $6283.91$ ,  $6613.9$ . The fact that these lines are wider and shallower than interstellar D lines of the same equivalent width is clearly established. Certain correlations suggest that the source of these lines may have a physical relationship to the particles which cause space reddening, but the chemical origin remains unknown.

#### NEW INTERSTELLAR LINES

An interesting result of the study of the spectrograms of very distant early-type stars taken with the instruments at the coudé focus of the 100-inch telescope is the discovery of several new interstellar lines. Of these, two lines in the infrared near  $\lambda 7700$  have been identified by Dunham as due to neutral potassium, and a very faint absorption line at  $\lambda 4226.7$  as neutral calcium. The neutral sodium pair near  $\lambda 3300$ , observed at the Lick Observatory many years ago, is a prominent feature. A few other faint lines in the blue and near ultraviolet observed by Dunham as very sharp and narrow lines, and hence almost certainly of interstellar origin, remain unidentified.

Of particular interest are three well-marked interstellar lines in the spectra of several stars the wave-lengths of which,  $3383.78$ ,  $3241.99$ , and  $3229.18$ , are found by measurements by Dunham and Adams to agree with those of three prominent ultimate lines of ionized titanium. A fourth line at  $\lambda 3072.97$ , which should be present, has also been observed and serves to establish the identification with titanium. No other lines of  $Ti\ II$  have been detected.

The  $Ti\ II$  lines which are observed all arise from the lowest energy state in the atom. This is in accordance with expectation, since an atom in interstellar space will rarely be disturbed either by collisions or by the absorption of radiation. The lowest level consists of four sublevels having differ-

ent inner quantum numbers, and the observed lines all arise from the lowest of these. The next level, which requires an excitation of only 0.015 volt, shows no transitions, an indication that nearly all the atoms are in the lowest sublevel. When light is absorbed from this lowest level some of the atoms must necessarily move into the next sublevel, and, since they do not remain there long enough to absorb light, they must return spontaneously to the lowest level. Evidence for a transition of this kind between two sublevels in the same term does not appear to have been obtained in laboratory experiments. Theoretical calculations show that the mean lifetime in the next-to-the-lowest sublevel is about 7 hours, and hence we may infer that an atom in the environment of interstellar space cannot experience collisions with its neighbors as often as once in 7 hours. The resulting upper limit for the mean density of the interstellar gases is about  $10^{-20}$  gr/cc. Other arguments indicate that the density is probably still lower.

The presence of the neutral calcium line  $\lambda 4226.7$ , if verified, would provide the first instance of an interstellar element which shows spectra of its atom in two stages of ionization. The observed ratio of the intensities of lines from the two types of atom offers a possible means of inferring the density of electrons in interstellar space.

The unidentified interstellar lines do not correspond to ultimate lines of any neutral or ionized atom. There remains the possibility that they are due to molecular absorption. Under laboratory conditions a molecule always yields a complex band spectrum, but the simplicity of the interstellar titanium spectrum, showing as it does transitions only from the absolute ground level, suggests that a molecule under similar conditions might have a greatly simplified spectrum consisting of but a few lines. This possibility is under investigation by Dunham.

#### STELLAR SPECTROPHOTOMETRY

Measurements of the total intensities of absorption lines in stellar spectra have been continued by Dunham during the year. Curves of growth relating the numbers of active atoms to the intensities of the lines have been determined, and these have made possible a study of the degree of ionization in the stellar atmospheres. Preliminary values for temperatures and electron pressures have been derived for  $\beta$  Orionis (gB8),  $\alpha$  Canis Majoris (dA2),  $\alpha$  Cygni (gA2),  $\alpha$  Canis Minoris (dF5),  $\epsilon$  Aurigæ (gF5),  $\alpha$  Persei (gF5), and  $\gamma$  Cygni (gF8). A catalogue containing all classified lines in many of the most important laboratory spectra, which has been prepared by Miss Carlson, has been invaluable for this work.

#### MISCELLANEOUS

A series of observations covering the recent eclipse of  $\zeta$  Aurigæ was obtained by Wilson and Christie and the spectrograms are being measured preparatory to a discussion of the material. Wilson is also engaged in a study of line-intensity variation in RR Lyræ and of the structure of the absorption lines of  $\alpha$  Cygni. Many variable stars, especially those with periods between 50 and 150 days, have been under observation by Joy, and Sanford has obtained numerous spectrograms of stars of type N, stars with



composite spectra, and others from the general radial-velocity program. Some of these were photographed in the infrared with the coudé spectrograph and Schmidt camera. Christie has several long-period spectroscopic binaries under investigation.

## GALACTIC NEBULÆ

### THE EXPANDING RING NEBULA IN CYGNUS

Measures by Hubble of the large ring nebula in Cygnus, over an interval of 27 years, indicate that the opposite segments, NGC 6960 and 6992, are moving rapidly outward at the rate of about 0".06 per year. This value is a revision of the provisional estimate of about 0".1 given in the Annual Report for 1925-1926 (Year Book No. 25). If the expansion has been uniform, 150,000 years have been required for the ring to reach its present dimensions.

### PLANETARY NEBULÆ

Photographs by Duncan confirm the faint envelope surrounding the Ring Nebula in Lyra found in 1935 and reveal a similar envelope 110" in diameter about the small green planetary NGC 6826. The latter shows well on a 60-minute exposure on an Imperial Eclipse plate and on a 100-minute exposure on Agfa Supersensitive Panchromatic film. Other photographs, with exposures of one to two hours, give negative results for NGC 6210, 6543, 6572, 6804, 6905, 7009, 7026, and 7027.

Photographs of a number of planetaries by Baade and Minkowski with the interference spectrograph confirm in a general way the results obtained at the Lick Observatory. The internal motions seem, however, to be much more complicated than those predicted on the simple assumptions of pure expansion and rotation. A relatively simple case, NGC 6826, is now under investigation.

### RED AND INFRARED PHOTOGRAPHY OF NEBULÆ AND CLUSTERS

Baade and Minkowski have used the high-speed red and infrared plates now available for the exploration of fields hitherto inaccessible because of prohibitive exposure times. The central part of the Orion Nebula, especially Trumpler's Trapezium cluster of stars, was photographed in the infrared, and spectrophotometric measures were made between  $\lambda 4000$  and  $\lambda 9000$  on early-type stars connected with the nebula. The results indicate that most of the stars are affected by selective absorption, which can be attributed to particles with diameters of the order of 150  $\mu$ .

The Eastman *Ha*-special plate, sensitive to about  $\lambda 6700$ , was found to be excellently adapted for photography in the red, and especially for the partial penetration of obscuring clouds in the Milky Way. Ammoniating increases the red sensitivity about one magnitude without perceptibly increasing the chemical fog. Startling results were obtained in photographing a number of heavily obscured globular clusters. Objects like NGC 6553, although they appear as poor clusters on blue-sensitive plates, were found to be extremely rich in stars. In several cases, the high color excess of the clusters (previously measured by Stebbins and Whitford) is shared by the



surrounding star fields. These appear extraordinarily rich on the red plates and suggest that a large part of the color excess must be due to relatively near-by clouds.

Test plates in the region of the galactic center indicate that strong reddening affects practically all of the partially obscured Milky Way star clouds. A program is now under way to survey the region with the greatest available penetrating power both in the red and, if possible, in the infrared.

### EXTRAGALACTIC NEBULÆ

#### CARD INDEX OF PHOTOGRAPHED NEBULÆ

A card index of catalogued nebulae on plates with the Mount Wilson reflectors has been completed by Miss Carlson. The file now includes data on about 1500 NGC objects and about 500 of the brighter objects in the *Index Catalogues*. The data are being used in a detailed study of the sequence of classification and statistical investigations of structure and contents.

#### IC 1613

Baade, in his study of the neighboring extragalactic system IC 1613, has reduced all the photometric data to a homogeneous system. The process includes a determination of the color equation introduced in 1935 when the silver coats on the telescope mirrors were replaced by aluminium. The color equation, it was found, can be avoided when desirable by using a suitable filter (e.g., Schott GG1) with the aluminized mirrors.

The period-luminosity curve in IC 1613 has been extended to periods of about 4 days.

#### PHOTOELECTRIC MEASURES OF MAGNITUDES AND COLORS

Stebbins and Whitford have completed the photoelectric measures of magnitudes and colors of 165 extragalactic nebulae on which they have been engaged for several years. Nebulae of Hubble's types E, Sa, and Sb are nearly uniform in color; those of type Sc are more varied, owing presumably to the presence of giant stars. Comparisons of colors and spectra suggest selective absorption within the nebulae but furnish no evidence of selective absorption in internebular space.

From the colors of nebulae, globular clusters, and B stars it is found that the ratio of selective to total space absorption within the galactic system is smaller in high than in low latitudes. The sun is assumed to be immersed in a dark layer of small selectivity near the galactic plane, while clouds of greater selectivity are present in nearly all directions along that plane but not immediately about the sun.

#### SPECTRA OF NEBULÆ

Apparent radial velocities and spectral types of 34 nebulae have been measured during the year by Humason. Of these nebulae, 28 are isolated systems and 6 are members of the Virgo cluster. The velocities of the latter fall within the limits previously observed in the cluster.

Using the spectrograph designed for interferometry at the Cassegrain focus of the 100-inch, Humason has also obtained five spectrograms of

NGC 221 on the comparatively large scale of 80 Å per mm at  $H\gamma$ . Well-exposed spectra from about  $\lambda 3900$  to  $\lambda 5000$  were recorded in 6 hours, as compared with about 40 hours required with the equipment previously available. The great advance in speed permits an extensive survey of bright nebulae on the larger scale.

#### SPECTROGRAPHIC ROTATIONS

Humason has measured spectrographic rotations in NGC 3115 (E7) and NGC 4111 (formerly classed as E7, but now recognized as an early Sa on edge). In NGC 3115, where the luminosity falls smoothly from the nucleus outward to undefined boundaries, the rotation follows the linear law

$$r = 9.8x + 640 \text{ km/sec,}$$

where  $x$ , the distance from the nucleus along the major axis, is expressed in seconds of arc and is counted positive on the north-following side of the nucleus. The measures on three spectrograms have been carried out to  $x = \pm 45''$ .

In NGC 4111, the rotation, also from three spectrograms, obeys the linear law

$$r = 35x + 810 \text{ km/sec}$$

over a central lens whose major diameter is about  $12''$ ,  $x$  being positive on the south-following side of the nucleus. Thereafter, out to at least  $50''$ , the rotation decreases with increasing distance in a manner which suggests the operation of an inverse quadratic law. The luminosity-curve along the major axis shows at least two flat sections, one beginning at about  $10''$  and the other at about  $35''$  from the nucleus. As in the half-dozen other early-type spirals which exhibit the same form of luminosity-curve, the flat sections are assumed to indicate the positions of spiral arms.

#### DISTRIBUTION OF NEBULÆ IN DEPTH

The distribution of nebulae in depth has been investigated by Hubble, using four Mount Wilson surveys and a fifth made by Mayall at Mount Hamilton. The surveys, reduced to a homogeneous system, represent about 100,000 nebulae and extend to about the effective limits of the 100-inch reflector.

The data are closely represented by uniform, large-scale distribution, provided the apparent magnitudes are corrected by increments,  $\Delta m$ , which are linear functions of distance:

$$\log \Delta m = 0.2(m - \Delta m) - 4.239.$$

In order to avoid a symmetrically increasing density outward, the corrections are attributed solely to the dimming effects of red shifts. Then, from the law of red shifts,  $d\lambda/\lambda = f(m)$ , it follows that  $\Delta m = 2.94 d\lambda/\lambda$ .

The interpretation of the results involves cosmological theory. The law of distribution and the law of red shifts furnish a provisional, empirical test of the theory of expanding universes which obey the relativistic laws of gravitation. The data are consistent with only one model—a monotonic universe of the first kind—which is closed, small, and quite young.

On the other hand, if red shifts are not velocity shifts, but are due to some unknown cause which does not involve motion, the observable region is thoroughly homogeneous and is too small a sample to indicate the nature of the universe as a whole.

## LABORATORY INVESTIGATIONS

### THE SPECTRUM OF EUROPIUM

Russell and King are cooperating in an investigation of the arc spectrum of europium, *Eu* I. The structure of this spectrum is simpler than those of most rare-earth spectra, since the normal state of the doubly ionized atom is the single level  $4f^7 \text{ } ^8\text{s}^0$ . The addition of two electrons to this gives numerous terms of multiplicities 10, 8, and 6. All those arising from the added electrons  $6s^2$ ,  $6s6p$ ,  $6s7s$ , and  $6s6d$  have been found, all but one from  $6s5d$ , and many others from  $6s8s$ ,  $6s7p$ ,  $6s7d$ ,  $6s5f$ ,  $5d6p$ ,  $5d^2$ , and  $6p^2$ . A number of strong low-temperature ultraviolet lines do not fit into this scheme, and probably represent transitions from the ground-state  $4f^7 \text{ } 6s^2 \text{ } ^8\text{s}^0$  to the configurations  $4f^6 \text{ } 6s^2 \text{ } 5d$  or  $4f^6 \text{ } 6s \text{ } 5d^2$ .

More than 800 lines out of a known total of about 1650 have been classified, including a large majority of the stronger ones. The determination of the relative positions of the energy levels arising from different configurations should aid in interpreting other rare-earth spectra.

On the experimental side, King has extended the arc and spark spectra of europium to  $\lambda 2100$  and, in the infrared, beyond 10,000. A generous amount of this rare substance donated by Dr. H. N. McCoy has made it possible to obtain many strong spectrograms which supplement the previous collection, and provide improved furnace spectra for the temperature classification. The fainter lines of *Eu* I and *Eu* II thus obtained are needed for the completion of the term analysis and, with the extensions mentioned, have increased the combined list to approximately 2800 lines. The remaining wave-length measurements will provide greater accuracy in the case of difficult lines.

### PHOTOMETRY OF ABSORPTION LINES

Photometric measures of absorption lines in electric-furnace spectra have been continued by R. B. King and A. S. King. The results for the spectrum of *Fe* I were reported last year, but additional spectrograms have been made to coordinate the measures in different spectral regions. This work has increased the number of measures and has given greater accuracy to the final *f*-values, the factors proportional to the number of atoms producing individual spectral lines.

A corresponding set of measures for absorption lines of *Ti* I between  $\lambda 3100$  and  $\lambda 6700$  has also been completed. In this investigation photometer tracings have been made for about 80 spectrograms, and *f*-values obtained for 227 lines in 66 multiplets. These titanium lines arise from ten low terms with excitation potentials ranging from 0.0 to 2.5 volts.

### SPARK SPECTRUM OF IRON

Photographs of the spark spectra of iron, chromium, and nickel have been made by King, using very powerful discharges from the large laboratory

condensers. The iron spark lines have been measured for wave-lengths greater than  $\lambda 5000$ , in which region comparatively few lines of *Fe II* had previously been identified in the laboratory. The new spectrograms show 122 lines of *Fe II* between  $\lambda 5018$  and  $\lambda 7711$ . The agreement of these with solar lines in the *Revised Rowland* is very close except in a few cases, chiefly in the infrared. In addition to the solar lines of *Fe II* previously observed in the laboratory and some others predicted from term values, the new material identifies 66 solar lines as due at least in part to iron. The origin of 47 of these is left blank in Rowland, while the other lines may be blends, usually with atmospheric or band lines. Since 56 of the new identifications are for solar lines of the lowest intensities ( $-2$  or  $-3$ ), apparently few, if any, lines of *Fe II* remain to be identified in this region of the solar spectrum.

Short studies carried out by King include an improved set of electric-furnace spectrograms of titanium in the infrared, further experiments with Minkowski on the photometry of furnace emission lines, tests of the purity of europium samples intended for the Harvard atomic-weight determinations, and an examination, with Professor F. A. Jenkins, of the University of California, of the band spectrum of graphite from the Elden meteorite. No evidence was found that an unusual proportion of the heavy isotope of carbon is present in this meteorite as compared with terrestrial graphite.

#### VACUUM SPARK

Using the large condenser, Anderson has devoted his attention to the development of the vacuum spark as a general laboratory source of light for spectroscopic work. It was very soon found possible to arrange the spark circuit in such a way that equally bright sparks can be obtained at all pressures from atmospheric down to one or two hundredths of a millimeter of mercury. The apparatus is not convenient for use with the extremely low pressures of the so-called hot spark, but it is now being modified to make this possible. A few elements, among them iron, copper, lead, and manganese, have been used as spark terminals and their spectra photographed with the 1-meter concave grating at pressures within the range mentioned. In general, it is found that from 5 to 10 sparks will give a spectrogram of average density with the spectrograph employed. This indicates that there should be no serious difficulty in using this source with the 15-foot concave grating.

#### RULING MACHINES

The study of the new ruling machine by Babcock has been directed chiefly toward the identification of the sources of accidental errors. Since these errors are difficult to observe by the interference method unless expensive recording apparatus is kept in operation, a large amount of ruling has been done, and appreciable progress has been made in interpreting their effects. In spite of refinements in parts of the machine and in certain accessories temporarily installed, it has not been possible to remove these errors; but their origin has now been clearly demonstrated. A program of reconstruction sufficiently inclusive to eliminate them has been mapped out.

During the year two 6-inch plane gratings were ruled on the new machine especially for the solar eclipse program of 1937, and three 4-inch gratings



suitable for spectrohelioscopes. Three 4-inch gratings were also ruled on the old machine.

A small aluminizing chamber has been made in the machine shop and is now being used to study improvements in surfaces on which gratings are to be ruled.

A simple visual photometer has been built into the spectroscope for testing gratings, which permits a rapid determination of the intrinsic brightness of a ruled surface for a few points in the spectrum. Extensions to the photographic regions are projected. Results thus found are important. They show, for example, that one of Wood's gratings ruled on an evaporated film of aluminium returns about 60 per cent of the incident monochromatic green radiation in the first order. Even on speculum castings, our own gratings, under similar conditions, give as much as 40 per cent—a disparity corresponding to the difference of reflecting power for speculum and for aluminium.

Further improvements in the new machine have been the substitution for the mechanical relay of an electronic one which keeps the temperature-range within about  $\pm 0.02$  C, and an application of the Michelson interferometer to the adjustment of the thrust bearing of the screw, which has proved superior to the usual method when the area of the plane surface is small, as is the case with a diamond bearing. The small errors in the spacing gear have been further reduced so that the gear is now sufficiently accurate.

### PUBLIC RELATIONS AND THE NEW AUDITORIUM

The new auditorium and exhibits building for the use of the general public on Mount Wilson was completed during the winter and opened for use in March. An interesting occasion was the formal opening on June 14, when President Merriam of the Institution found it possible to be present and spoke before an invited group of guests on "The interpretation of the results of research." Dr. Adams at this time outlined the growth of public interest in the work of the Observatory as indicated by the remarkable increase in the number of visitors during recent years.

The auditorium building has proved most satisfactory in operation and with its new exhibits room fills a very definite need. On Friday evenings, when the 60-inch telescope is available for public use, lectures are given in the auditorium immediately preceding observations with the telescope. The exhibits room is also open every afternoon before demonstration of the 100-inch telescope. More than 50,000 visitors have seen the exhibits and 100-inch reflector during the past year, and over 10,000 have made observations with the 60-inch telescope. Hickox and Christie have given the Friday evening lectures and usually have served as curators in the exhibits room during the hours when it is open to the public.

### CONSTRUCTION AND MAINTENANCE

Owing to increased use of the road leading through the grounds of the Observatory and the prevalence of dust during the summer months, the portion of the road between the west line of the Observatory grounds and the

auditorium has been improved with an oil pavement. The ground immediately about the 60-inch telescope building has also been oiled with excellent results. Considerable work necessitated by the severe storms of the winter has been carried on upon the roads and retaining walls to prevent erosion. The large house of temporary construction used in the projection and transformation of lunar photographs was considerably damaged by the heavy snows of the winter but has since been fully restored. All of this construction and much general maintenance and repair work have been under the direction of A. N. Beebe, Superintendent of Construction.

The electrical transmission line was broken by the severe ice and snow storms of late December, and for several weeks the emergency power plant on Mount Wilson was in use to provide for the operation of the telescopes. Sidney Jones, Engineer, and Kenneth de Huff, Assistant Engineer, carried on this work in addition to the maintenance of the mechanical and electrical equipment of the buildings and instruments and the installation of all the wiring of the new auditorium.

#### DESIGN, INSTRUMENT, AND OPTICAL SHOPS

In the engineering department E. C. Nichols, assisted by H. S. Kinney, has completed the design of numerous instruments and pieces of apparatus, including, among others, a second spectrograph planned for nebular observations at the Cassegrainian focus of the 100-inch telescope, the mounting for the correcting lens at the Newtonian focus, a new gear box for the declination slow motion, a new plate-holder mounting for the 60-inch telescope, and a vacuum aluminizing chamber for mirrors and grating plates 11 inches or less in diameter. All this apparatus and many other smaller instruments and attachments have been constructed in the instrument shop, which has remained under the charge of Alden F. Ayers. During the recent illness of Ayers the shop has been under the immediate direction of Albert McIntire. The equipment for the total solar eclipse of June 8 required considerable time, both for design and for construction.

In the optical shop the most extensive undertaking has been the refiguring of the 8-inch Ross zero-power correcting lens for the 60-inch telescope and the approximate completion of the 7.5-inch Ross three-lens corrector for the 100-inch. This work has been carried on by John S. Dalton. Hendrix and Dalton have figured optical parts for the new nebular and interferometer spectrographs and the apparatus taken to the solar eclipse of June 8, and have completed many small mirrors, prisms, grating plates, and other units of the optical instruments.

#### THE LIBRARY

During the past year the library has added 206 volumes, 37 by gift, 77 by purchase, and 92 by binding; the total number is now 13,350, with over 10,000 pamphlets. The number of serial publications received regularly in 1937 was 141; of these 42 were gifts or exchanges, as were also the publications of more than 200 observatories and research institutions, which are published at irregular intervals.



## DIVISION OF PLANT BIOLOGY <sup>1</sup>

H. A. SPOEHR, CHAIRMAN

An indication of the growth in the application of science in both governmental and private undertakings may be seen in the increased number of requests which have been received during the past few years for information concerning some of the research activities of this Division. The gap between the discovery of facts and their application is narrowing rapidly. Agencies which make use of scientific facts and principles have highly trained experts who know how and where to obtain the special information needed for their particular purposes. The dissemination of information for such purposes and the cooperation with other agencies can under certain circumstances be a source of intensified effort and stimulus for investigators in an institution such as ours.

There is still an enormous and promising field in the chemistry of natural products, particularly those of plant origin. This has a bearing on the development of our knowledge of the factors and influences determining plant growth, the elements in plant crops of importance to human nutrition, and also on the vast field of raw materials of value to industry. The products manufactured by the plant through photosynthesis constitute an inexhaustible supply of valuable and cheap raw materials from which a multiplicity of substances of great value to industry can be synthesized by chemical means. The plant manufactures predominantly materials consisting of units of five and six carbon atoms, exemplified in the pentose and hexose sugars, which are variously combined to make up starch, cellulose, pectins, and the like, from which an almost inconceivably large number of products are elaborated by the plant itself and which can serve as raw material for a host of artificially synthesized products.

But a few years ago the pigments of plants, as a subject for scientific investigation, had chiefly only academic interest. With the development of our knowledge of the chemical structure and properties of these substances came an understanding of the important function of some of them in animal nutrition and metabolism. Fundamental researches on these carotenoid pigments have made possible significant advances in the science of nutrition, and have found application not only to human nutrition but also to many branches of agriculture, such as dairying, animal husbandry, and poultry raising.

There has recently been a strong growth of public interest in the arid parts of the United States on account of the comprehensive studies of land use, soil conservation, and range restoration which have been undertaken by various agencies of the federal government. The Desert Laboratory has met increasing demands for basic physical, climatological, and botanical data of immediate value to governmental and private undertakings concerned with the use of arid regions. Knowledge which has highly practical value today has, in many cases, grown from work which was begun many years ago because of its manifest scientific importance. This is particularly

<sup>1</sup>The Central Laboratory of the Division is located at Stanford University, California.



true of the study of changes in vegetation over long periods and of the investigation of the distinctive features in the life histories of some of the very dissimilar plant types which successfully meet arid conditions.

Also originating from the work of the Desert Laboratory, a wealth of practical information has resulted from the extended observations, now covering almost half a century, which have been made by Mr. Godfrey Sykes, of the physiographic history of the delta region of the Colorado River. The rhythm of flow of this stream has recently been fundamentally changed by the construction of the Boulder Dam. The long investigation constitutes a most valuable record of the dynamics of the stream and the manner of deposition of detrital material within the deltaic area, which comprises a basin of over three thousand square miles and contains one of the most productive irrigated agricultural areas of the world. This life work, which includes a study of the early human history of the region, is being brought to publication, two volumes having already appeared.

For a great many years one of the major subjects of study of Dr. F. E. Clements has been the ecology of the Great Plains and its bearing on the agriculture and human population of this immense area. The development through these studies of a comprehensive viewpoint on this subject has been of assistance in correcting a number of popular misconceptions regarding the future of this region. It is argued that if the past can be taken as a guide, the recent drought period in this area was not the first of such events and it will not be the last, and, moreover, that the dust storms which accompany the drought are primarily due to disturbances wrought by man. Dr. Clements considers that a misconception resides in the assumption that short-grass is the natural vegetation of the plains; that short-grass is rather a consequence of overgrazing. Evidence has been accumulated to show that the true climatic grassland is a mixture of short grasses with such taller ones as wheat and spear grass, which indicate a climate suitable to wheat-growing in the main.

With the discomfort and tragedy of dust storms before the nation, it was inevitable that proposals to regrass all or most of the crop lands of the Great Plains should meet with practically universal approval. However, it is pointed out that this failed to take into account the slowness of natural recovery in abandoned fields, which often require thirty to forty years, and the difficulty and cost of artificial regeneration by seeding and planting. Evidence has also been presented in support of the contention that the Great Plains are a valuable reservoir of soil fertility, from which satisfactory yields of wheat can be secured through large-scale, progressive methods. As a result of these prolonged climatological and ecological investigations it is concluded that long-range forecasting of rainfall and drought must come to play an important part in planning crops and insuring production. Even more helpful at present is believed to be the use of measurement of soil moisture throughout the year to determine the probable success of winter wheat or the desirability, with deficient rains, of plowing under in the spring in order to save the moisture for the following year.

In experimental taxonomy, the nature of the barriers that limit natural species and subdivisions of species have been further investigated. One

large second-generation hybrid population of tarweeds demonstrated that the original parents, which were regarded as different subspecies of the same species, actually represented transitional stages between subspecies and full-fledged species. Here, experimental evidence showed that the evolutionary differentiation from a subspecies to a species may be a gradual and cumulative process. In contrast is the rare situation in which species may arise essentially *de novo* as the result of hybridization between preexisting species. Supporting evidence to this effect was contributed from this laboratory a few years ago, and evidence is now accumulating toward the establishment of two additional cases of this sort. Conclusive evidence that subspecies of a species may differ in chromosome number has been given by a second-generation hybrid population of 2500 individuals. So far as we know, this is the first case in which the difference in chromosome number, through incompatibilities, has not created barriers of at least specific importance.

The investigations of recent volcanic ash deposits in Alaska by Dr. R. W. Chaney have yielded valuable information on the mode of accumulation of older plant-bearing deposits in western America. Many of the leaves which have been preserved in the Tertiary record of Oregon and California were apparently buried by showers of ash similar to that which accompanied the eruption of Mount Katmai in 1912.

During the past year a large part of the climatological work has been expended upon cycle analysis and its various ramifications. The cyclograph, an analyzing instrument invented in 1913-1914 for application to the tree-ring and climatic records of Arizona, has been rebuilt with improved accessories and exhibited in Washington at a third cycle conference. Dr. Douglass is of the opinion that the word "cycle" should be defined in terms of this instrument, making it refer to variable cyclic phenomena, so that it would be a general term under which "period" would be the special case in which the recurrence is permanent and exact. In addition to this cycle work a very favorable result has been obtained by Mr. Schulman in comparing ring growth at Carmel with rainfall distribution there. When this is done with care upon trees selected as to "climatic" topography, the correlation between the two is 75 per cent ( $\pm 0.05$ ). A volume on cycles by A. E. Douglass has been published by the Institution and also a volume on methods and principles of tree-ring analysis by Dr. W. S. Glock. A photographic ring chronology covering 1925 years is nearly completed. The results from these long investigations have found many applications in other fields of scientific work and are being extended into various practical applications.

### BIOCHEMICAL INVESTIGATIONS

By H. A. SPOEHR, J. H. C. SMITH, H. H. STRAIN, AND H. W. MILNER

#### LEAF PIGMENTS

The application of chemical methods to the interpretation of the reactions occurring in living organisms depends in a large measure upon the isolation of biologically important substances and the study of the chemical and physical properties of these substances under controlled conditions. Of necessity the extraction of many of these substances involves the killing

of the organisms from which they are derived. This is especially true of plant material. To what extent the substances sought undergo changes during the process of killing and of extraction and thus when isolated represent modifications, qualitatively or quantitatively, of the materials as they exist in the living organism has been a troublesome problem and the cause of much controversy.

There are indications that after the death of the cells many of the biologically important substances in leaves undergo rapid modification and loss in quantity. These changes are apparently the result of oxidative disorganization of the cells accompanying death. The observations of the rapid post-mortem changes in the constituents of plant tissue are of significance for the quantitative determination of many of these substances, a fact which has not been sufficiently realized in the methods which have been generally employed and which has undoubtedly resulted in many erroneous conclusions, especially in connection with some of the more sensitive plant pigments.

Important activities of leaf cells, such as photosynthesis, are readily impaired by slight injuries or derangement of the finer structure of the cells. The evidence is growing that such derangements are accompanied by chemical changes, which, although they involve only relatively small amounts of material, affect essential components which are extraordinarily sensitive to oxidation by the air. If leaves are killed by means which do not usually inactivate enzymes, such as freezing, grinding, or treatment with anesthetics or noxious gases, a rapid oxidation of the yellow pigments takes place. This reaction occurs only in the presence of oxygen. It is probably associated with some form of enzyme action, for it can be prevented by exposing the killed plant material to reagents and conditions which inactivate enzymes, such as heat, salts of heavy metals, and proteolytic enzymes. It is also inhibited by antioxidants and occurs in the presence of acids but not in an alkaline medium. There is indication that the carotenoid pigments in leaves occur in combination with fat and protein and it is in this combined state that these pigments are particularly sensitive to oxidation.

The carotenoid pigments of etiolated leaves are oxidized very rapidly and almost completely when the leaves are killed with anesthetics. Under certain circumstances the reactivity of the carotenoid pigments, as measured by their susceptibility to oxidation, can be appreciably decreased. Thus when etiolated leaves which have been killed by standing in vacuum are then exposed to air, the quantity of pigment which is oxidized is considerably less than that which disappears when the leaves are killed in air with anesthetics. Apparently the killing of the cells under anaerobic conditions effects changes in the pigment complex which decrease its susceptibility to oxidation. Also, as etiolated leaves develop and become green, there is a decided decrease in the quantity of pigment which oxidizes rapidly when the leaves are killed with anesthetics. Artificially prepared suspensions of carotenoid pigments which have been stabilized with proteins and fats are not oxidized rapidly in acid solution.

The carotenoid pigments contained in yellow or variegated leaves, in yellow autumn leaves, and in the leaves of certain yellow varieties or strains



of plants are not oxidized rapidly when the plants are killed with anesthetics. This is also true of the pigments in roots, fruits, and flowers. Whether these differences in the reactivity of the carotenoids in various plant tissues are due to differences in the structure and composition of the plastids or to differences in the state of combination of the pigments has not been determined. In all probability, however, the susceptibility to oxidation of the carotenoids in leaves is due to their association with other substances in the chloroplasts and perhaps also to the structure of the chloroplast itself.

The oxidation of the carotenoid pigments which takes place when leaves are killed in air, with anesthetics or by the other means which have been mentioned, is accompanied by a number of other oxidative reactions. This has now been demonstrated by various independent observations involving quite different analytical procedures. Chromatographic adsorption of the pigments contained in the extracts of etiolated and of green leaves, killed with anesthetics in the presence of air, has demonstrated that large quantities of fatlike substances are also oxidized. Living leaves contain appreciable quantities of highly fluorescent, colorless substances which are also adsorbed on magnesium oxide columns. These fluorescent substances are rapidly converted into nonfluorescent oxidation products when leaves are killed with anesthetics in air. Moreover, the absorption spectra of the chlorophylls extracted from the killed leaves are different from the absorption spectra of solutions obtained by the extraction of living leaves with the same organic solvents.

In this connection brief mention may be made of the results of investigations on chloroplasts which have been carried out in cooperation with Dr. Elliot Weier. About twenty years ago the Austrian plant physiologist Molisch called attention to the fact that chloroplasts, when in the living condition, have the capacity of reducing solutions of silver nitrate. If, however, the cells containing the chloroplasts are killed, the reaction does not take place; the reaction can, in fact, be employed as a test as to whether the chloroplasts are living. Although some controversy has arisen as to the universal validity of this reaction, Dr. Weier has in the main substantiated the claims of Molisch. It has, however, also been found that the nonappearance of the reducing reaction with killed chloroplasts is due to an oxidative destruction of some material or to oxidative disorganization of some component of the chloroplasts, which occurs during the process of killing the leaf material. If the leaves are killed in an atmosphere containing no oxygen or only very small quantities of this gas, and the tests are also carried out in such an oxygen-free medium, the killed chloroplasts are still capable of effecting a reduction of the silver nitrate. Moreover, it is possible with cold water to extract from the killed leaves material which reduces silver nitrate in the cold, provided the killing and extraction processes are carried out in an atmosphere free of oxygen. Although this reducing substance is highly susceptible to oxidation when contained in the leaf, it is appreciably more resistant to oxidation after it has been extracted, though in the extracted state it can also be oxidized to a nonreducing substance by means of iron salts. The chemical nature of this highly reactive chloroplast material has as yet not been established, and various aspects of the conditions under



which it is formed are still under investigation. Photosynthesis occurs only in living cells; even slight injury to these cells or to the chloroplasts inhibits the process. It is therefore of the greatest importance to determine the significance of the living cell, its structural peculiarities, and the nature of the reactive materials contained in the chloroplasts. The reactions of the chloroplasts are of particular interest in this connection as evidence of the value of histochemical methods as an aid to the investigation of the components of the photosynthetic apparatus.

Colorless fluorescent substances which were isolated from green leaves (Year Book No. 35, p. 201) and which, from their adsorption behavior, appear to resemble the carotenoid pigments have been isolated from many species of plants. These substances occur in the leaves of plants which contain beta-carotene and in those which contain both alpha- and beta-carotene. They occur in small quantities in the roots of the white carrot and in relatively large quantities in the roots of the yellow carrot. These colorless fluorescent substances occur in the chlorophyll-bearing portion of leaves rather than in the epidermal layers. The rapid oxidation of these fluorescent substances in carefully killed etiolated leaves suggests that the fluorescent compounds are associated with the carotenoids in the plastids. When isolated from leaves and from carrot roots by chromatographic adsorption, the colorless fluorescent substances are oxidized very rapidly. The oxidation products are not fluorescent and are much less soluble in organic solvents such as petroleum ether than are the original fluorescent compounds.

The experience in isolating and purifying the leaf xanthophylls which has been gained during the past several years has now been applied to an investigation of the properties of the very sensitive new xanthophyll pigment, eschscholtzxanthin, isolated from the petals of the California poppy, *Eschscholtzia californica* (Year Book No. 33, p. 179). This pigment has the formula  $C_{40}H_{54 \pm 2}O_2$ . It contains two hydroxyl groups and twelve double bonds. Its spectral absorption properties and those of its esters have been compared with the spectral absorption properties of the common leaf xanthophylls and their esters. Of special interest is the fact that eschscholtzxanthin absorbs oxygen from the air much more rapidly than do any of the naturally occurring carotenoid pigments which have been isolated thus far. The oxidation products of eschscholtzxanthin act as oxidizing agents toward reducing substances such as leuco indigo carmine. When the oxidation of eschscholtzxanthin is heated or illuminated, only traces of oxygen are evolved. Even though pure eschscholtzxanthin is oxidized very rapidly upon exposure to air, the pigment is not oxidized rapidly when the poppy petals are killed with anesthetics.

It has long been a question of some controversy whether red light stimulates the formation of carotenoid pigments in leaves. Much of the recent plant physiological evidence has indicated that such is not the case. This problem has again been investigated with the use of relatively large quantities of etiolated barley seedlings which contain small quantities of carotene. In one series of experiments, light ranging in wave length from 600  $m\mu$  to the infrared, and in another series, light ranging from 640  $m\mu$  to the infrared was used. In all the experiments a rapid increase of the carotenes and

xanthophylls as well as of the chlorophyll pigments in the etiolated barley seedlings was found. Determination of the absorption spectra of beta-carotene and of lutein, which are the principal constituents of the leaf carotenoids, reveals that these pigments absorb considerable light in the red spectral region. This is the same region in which chlorophyll exhibits maximum absorption. It remains to be established whether the formation of carotenoids in red light is the result of direct stimulation by the light which is absorbed in this spectral region or whether the formation of the carotenoids is the result of other secondary reactions in which possibly chlorophyll plays a rôle.

Determinations of the spectral absorption properties of the pigments extracted from leaves have revealed that, in the narrow spectral region of 470 to 500  $m\mu$ , the yellow carotenoid pigments absorb from 50 to 90 per cent of the total quantity of the light absorbed by all the pigments in the leaf extracts. Consequently measurements of the utilization of light of this spectral region by plants will be greatly influenced by the carotenoid pigments which are present. This fact stresses the importance of determining the efficiency of photosynthesis in this spectral region in order to obtain further information concerning the possible function of the carotenoid pigments in the photosynthetic reaction.

#### ABSORPTION OF CARBON DIOXIDE BY THE UNILLUMINATED LEAF

During the past year the investigation of the mechanism whereby the leaf absorbs carbon dioxide from the atmosphere and utilizes it in the photosynthetic process has been directed toward the answering of two questions: (1) How completely reversible is the absorption of carbon dioxide by leaves? and (2) What substances in leaves act as carbon dioxide absorbents?

Experiments have demonstrated that the carbon dioxide which is absorbed by the unilluminated leaf can be recovered quantitatively. Therefore, the absorption process is completely reversible. This is true of living and killed leaf material. It is apparently the reaction of some purely chemical system.

A comparison of the absorption capacities of living and killed sunflower leaves showed that killed leaves possessed a greater absorption capacity than living material. The leaves were killed by freezing or at 100° and had a very low rate of post-mortem respiration. The difference in behavior of the living and killed leaves is probably due to the constant production of carbon dioxide by the living cells, which would afford a continuous supply of this gas to the absorptive agents and thus reduce the amount absorbed from the surrounding atmosphere. Another striking difference between living and killed leaves is that the former attain equilibrium with the carbon dioxide of the surrounding atmosphere within a few minutes, while the killed leaves require a very much longer time.

The identification of the substances responsible for the absorption of carbon dioxide has been a much more difficult problem. It is clear that water plays an important part herein, but the entire absorption can apparently not be ascribed to the absorptive capacity of water. The part that water plays has been determined largely by comparing the amounts of carbon dioxide absorbed by similar leaves in which the water content has been

varied through water loss from the leaves. As leaves lose water their absorption capacity for carbon dioxide also decreases. However, in most cases the decrease in water content resulted in a greater decrease in carbon dioxide absorption than would be predicted from the amount of water lost as calculated on the basis of the absorption coefficient of pure water for carbon dioxide. This conforms to what we know about the change in the absorption capacities of aqueous solutions as they become more concentrated. In this respect the water in the leaf behaves as if it were present in a dilute solution.

Within the pressure range 0.3 to 1 atmosphere, the amount of carbon dioxide absorbed is directly proportional to the pressure of this gas. If the amount of carbon dioxide absorbed per atmosphere of pressure is divided by the number of grams of water contained in the leaves, an apparent absorption coefficient for water can be obtained. This coefficient increases as the water content decreases. In most cases these apparent absorption coefficients are greater than the absorption coefficients of pure water. It appears, therefore, that leaves contain substances which absorb carbon dioxide in proportion to its pressure and that these substances are not lost during the evaporation of water from the leaves. Inasmuch as some species of leaves, particularly those with a sap of high acidity, have an apparent absorption coefficient less than that of pure water, it is very difficult to apportion to the water in leaves the proper fraction of carbon dioxide absorbed.

Much of modern theoretical speculation regarding the photosynthetic mechanism has assumed that chlorophyll is the component in the photosynthetic system which absorbs carbon dioxide. A comparison of the absorption capacities of etiolated, luteous, and albino leaves of the same species has shown that chlorophyll has no demonstrable effect on the absorption of carbon dioxide. Many cases were observed in which the carbon dioxide absorbed by chlorophyllous leaves was less than that absorbed by the non-chlorophyllous varieties. However, no large effect could be expected if it is assumed that each molecule of chlorophyll absorbs one molecule of carbon dioxide. It has been calculated that the chlorophyll in 10 gm. of leaves, for example, would absorb approximately 0.5 cc. of carbon dioxide if chlorophyll were capable of absorbing this gas. The detection of relatively so small an amount would be rendered uncertain by the variations in the physical and chemical conditions in different samples of leaves. Until the absorption by other constituents can be estimated more accurately the amount which can be apportioned to chlorophyll cannot be properly evaluated but, under any circumstances, apparently would be very small in comparison.

Measurements of the carbon dioxide absorbed by the leaf saps and by the solid constituents which remain after expressing the sap from the leaves have demonstrated that these residues as well as the leaf saps may be involved in the total absorption of carbon dioxide by the leaf. This was especially true for the more alkaline leaves such as the sunflower, which have a *pH* of approximately 7. Both the solid residues and the saps of such leaves absorbed a very considerable quantity of carbon dioxide in excess of the water present. This was not true, however, for the sap of the more acid



leaves of *Sedum præaltum*, which absorbed less carbon dioxide than the amount calculated for the water of the sap.

Analysis of the solid residues from sunflower leaves showed that calcium and magnesium were the chief basic constituents. Quantitatively there was more than enough of these elements to account for the absorption of carbon dioxide by the leaf residues. If calcium and magnesium compounds existed in the solid residues of sunflower leaves in such form as to react with carbon dioxide, it is most probable that they would form the relatively soluble bicarbonates when treated with an aqueous solution of carbon dioxide, and be thus extracted from the residue. The calcium and magnesium contained in the insoluble residue of sunflower leaves were, in fact, thus easily extracted, which gives strong indication that these alkaline earths could act as carbon dioxide absorbents in these leaves. It has previously been suggested (Year Book No. 25, p. 179 [1926]) that the absorption of carbon dioxide by killed leaf material results from the reaction of carbon dioxide with a carbonate. If the absorbing agents are carbonates, the amount of carbon dioxide that would be absorbed reversibly at a pressure of 1 atmosphere should be equal approximately to the amount of carbon dioxide that would be evolved from the original leaf material on treatment with cold dilute hydrochloric acid. The experimental evidence, though still incomplete, indicates that such is the case, and that calcium and magnesium may play an important rôle in the first step of the photosynthetic reaction.

#### AMYLOLYTIC ACTIVITY OF LEAVES

The investigations of the conditions effecting starch dissolution and amylolytic activity in leaves have been extended through the development of quantitative analytical methods. A primary objective of these investigations has been the determination of the manner in which environmental conditions affect the activity of enzymes in the leaf. Amylase was selected for this purpose because its action is fairly well understood and because methods for the quantitative determination of its substrate, starch, have also been developed to a satisfactory degree of precision. The amylolytic activity is thus used as an indicator of the condition of the cells in regard to enzymatic function.

In order to determine the rôle of oxygen in the starch dissolution of leaves, these have been subjected to a number of irrespirable gases and mixtures of these with oxygen. Different species vary greatly in their capacity to survive under these conditions. Certain leaves, such as those of the sunflower, can be kept under anaerobic conditions for as long as 24 hours without showing any signs of injury. Definite evidence has been obtained of starch dissolution in leaves which have been kept in nitrogen or in hydrogen, although the rate of starch hydrolysis under these conditions is noticeably less than in normal air. In pure carbon dioxide, starch dissolution does not occur; however, with even small admixtures of oxygen to carbon dioxide the starch is hydrolyzed though at a definitely inhibited rate. When leaves are confined in vessels containing air, or hydrogen or other irrespirable gases, the rate of starch dissolution is definitely less than when the living leaves are put in a stream of any of these gases. This difference in behavior of leaves in stream-



ing and in confined gases is apparently due to an accumulation of the products of respiration, either aerobic or anaerobic, in confined atmospheres. Under conditions of the streaming gases the products which are inhibitory to starch dissolution are constantly removed. By circulating the gas in a closed system containing the leaves the same inhibitory effects are obtained. But if in thus circulating the gases they are at the same time washed and so freed from products of respiration, the rate of starch dissolution approaches that attained in streaming gases. In this manner it was possible to demonstrate that the accumulation of carbon dioxide has a decidedly inhibiting effect on the rate of starch dissolution. Apparently, however, relatively small amounts of oxygen in the gas mixtures can counteract the effect of the accumulation of carbon dioxide.

Starch dissolution in living leaves must be taken as evidence of amylase activity. But the manner in which the various gas mixtures exert their influence on the amylolytic activity is not clear. It was necessary to improve the methods for the quantitative determination of the activity of amylase in leaves, and much time has been spent on modifying various details of procedure and establishing conditions which would yield analytical results of the desired degree of accuracy.

Plant material exhibits tremendous variability in amylase activity; not only do the leaves of different species of plants show very great differences in this regard, but leaves of the same species and age, even when the plants have been grown under the same conditions, exhibit a wide range of amylolytic activity. As a consequence, in order to obtain reliable results it has been necessary to carry out a large number of experiments involving a very extensive series of time-consuming analyses.

The hydrogen ion concentration of the medium has a pronounced effect on the activity of amylase; maximum activity is usually exhibited at a certain pH value, and above and below this value amylase activity decreases rapidly. The hydrogen ion concentration representing maximum amylolytic activity differs with different leaf material; some species of leaves exhibit maximum activity in a medium which is very nearly neutral, while that of other species is at a point of appreciably higher acidity. Another factor which has a pronounced influence on the amylolytic activity of leaves is the degree of water saturation of the leaf protoplasm. The entire carbohydrate economy of the leaf is strongly affected by the water balance; the dissolution of starch and its synthesis are in a large degree controlled by water saturation or water deficit of the leaf.

Amylolytic activity is preserved in the leaf for some time after death. After a leaf is cut from the plant the activity decreases rapidly, and if the leaf is allowed to dry in the air there is a further diminution in its starch-splitting capacity. However, if the leaf is first killed with toluene and then dried, the activity of the dried material is found to be equal to and frequently somewhat higher than that of the original living leaf. Killing with toluene has been found to be most satisfactory in this respect; other killing agents, such as chloroform, affect the amylase deleteriously and result in a dried leaf material of low activity. However, all dried leaf material gradually loses its

amylolytic activity, even if preserved in vacuum. Similarly leaf material which is preserved in toluene undergoes changes which result in the gradual loss of the activity of the amylase.

## INVESTIGATIONS ON THE CAMBIUM AND ITS DERIVATIVE TISSUES

BY I. W. BAILEY

### THE FINER VISIBLE STRUCTURE OF NATIVE CELLULOSE

Under high magnification, the cellulose matrix of both primary and secondary walls appears to be composed of aggregations of threads or fibrils which are held together, not by a "foreign" cementing substance, but by actual anastomoses and lateral interconnections. These anastomosing fibrils vary considerably in size, the finer ones grading down to the limits of microscopic visibility, even in much-swollen material. They may be aggregated into concentric or radial lamellæ of varying widths and porosities, thus giving rise to many diverse and complex structural patterns.

By measuring the thickness of a secondary wall before and after swelling, and by counting the number of constituent growth rings or lamellæ, it is possible to determine the approximate thickness of these zones in the unswollen wall of cotton hairs and of various types of tracheary cells. The narrowest growth rings grade down to  $0.1\ \mu$  or less in thickness. Each growth ring consists of two parts, a more porous lamella and a less porous lamella. The narrowest lamellæ appear to be composed of a single row of anastomosing fibrils which, therefore, grade down to approximately  $500\ \text{\AA}$  units in diameter. It is evident, accordingly, that the finest parts of the cellulosic matrix which may be rendered visible by swelling are anastomosing threadlike aggregates of chain molecules whose diameters approximate those of "micelle series" as defined by Freudenberg.

### THE STRUCTURAL VARIABILITY OF THE SECONDARY WALL AS REVEALED BY "LIGNIN" RESIDUES

Lignin and other noncellulosic substances may be deposited in the elongated, intercommunicating interstices of the cellulosic matrix, thus giving rise to two continuous, interpenetrating systems of different chemical composition. In the case of heavily lignified tissues, it is possible to dissolve either system without seriously modifying the continuity or the structural pattern of the remaining system. The structural residues obtained by these two methods are remarkably similar, the denser parts of one corresponding to the more porous parts of the other. Thus, the structural pattern of the cellulose may be reconstructed from the noncellulosic residue or vice versa. Swollen sections of the purified cellulose afford excellent objects for critical visual examination, but "lignin" residues are easier to prepare, and are preferable for photomicrography in dealing with lignified tissues, e.g. wood.

In the wood of both gymnosperms and angiosperms, walls or layers which persist as coherent structural residues upon treatment with strong mineral acids usually give an intense coloration with phloroglucin-HCl; whereas those which disintegrate commonly do not, although they may give a strongly

positive coloration with either the Mäule test or the chlorine-sodium sulphite reaction. Where the walls exhibit an intense coloration with the latter tests, but tend to disintegrate into a finely granular residue upon treatment with 72 per cent sulphuric acid, it is possible to obtain coherent structural residues by first soaking sections of the wood in a solution of vanillin or some equivalent reagent.

The structural patterns of the secondary walls of tracheids, fiber-tracheids, and libriform fibers are not constant for any particular species, but fluctuate more or less in different parts of the same stem and even, at times, of the same cell. Prevaillingly concentric, dominantly radial, and various intermediate radio-concentric structures occur in different parts of the stems of conifers and dicotyledons. In the case of coniferous tracheids, radial structural patterns are formed in parts of the stem and branches that are developing under the influence of geotropic stimuli. The so-called gelatinous fibers of dicotyledonous woods have a conspicuously radial or radio-concentric structure. There is some evidence to indicate that these fibers occur in parts of stems and branches that are developing under the influence of tropistic stimuli.

#### THE ORIENTATION OF CELLULOSE IN THE SECONDARY WALL OF TRACHEARY CELLS

Crystalline aggregates of iodine may be induced to form within the elongated interstices of the cellulosic matrix of the secondary wall. These elongated crystals are oriented parallel to the long axis of the fibrils of cellulose and therefore of the chain molecules. The crystalline aggregates are so conspicuous and so clearly visible microscopically that it is possible not only to detect such major variations in orientation of the cellulose as occur in passing from layer to layer of the secondary wall, but also to observe such fluctuations in orientation as occur within the limits of a single layer. In the case of normal three-layered tracheids, fiber-tracheids, and libriform fibers, the orientation of the cellulose of the outer layer and of the central layer of the secondary wall fluctuates more or less from specimen to specimen, from cell to cell, and in different parts of the same cell. Although the orientation of the cellulose may deviate, at times, in the successively formed growth rings or lamellæ of the central layer, there is no regular alternation of right-handed and left-handed helixes as hypothesized by various investigators. In the case of the large bordered pits of the earlywood of conifers, the cellulose has a circular orientation in the outer layer, but merely curves about the pits in the central layer. The less specialized types of dicotyledonous vessels resemble normal tracheids in having a three-layered secondary wall, whereas the more highly specialized types have walls of a much wider range of complexity and structural variability, owing to fluctuations in the orientation of the cellulose.

#### THE SIGNIFICANCE OF CERTAIN WOOD-DESTROYING FUNGI IN THE STUDY OF THE ENZYMATIC HYDROLYSIS OF CELLULOSE

There are certain fungi whose hyphæ perforate and move forward within the secondary walls of tracheary cells and fibers. The cavities produced by



these fungi are of two geometrical forms, i.e. (1) cylindrical with conical ends or (2) biconical, and are of remarkably constant angularity, regardless of the particular group of gymnosperms or angiosperms in which they occur. It is evident that the enzymatic activity of these fungi progresses along two predetermined sets of planes, (1) oriented parallel to the long axis of the fibrils and chain molecules of cellulose and (2) at an angle of from 20° to 25° to this axis.

During the dissection of the secondary wall into so-called fusiform bodies, the hydrolytic action of sulphuric acid, phosphoric acid, and cuprammonium hydroxide appears to progress along similar planes, as does the acetylation of cellulose. A careful study of these predetermined planes of chemical action during hydrolysis and acetylation should yield significant data regarding the submicroscopic configurations of cellulose.

### EXPERIMENTAL TAXONOMY

BY JENS CLAUSEN, DAVID D. KECK, AND WILLIAM M. HIESEY

The principles and problems of experimental taxonomy were restated in Year Book No. 35 (pp. 208-209). Coordinated investigations of this nature build their conclusions upon a wealth of new information, observational as well as experimental. The accumulation of such information is a slow process because of the number of details to be studied, the successive generations of plants needed, and the large number of systematic units to be investigated if results of general importance are to be obtained.

### COMPILATION OF MANUSCRIPT

During the past year many gaps were filled in the network of evidence, and we are now ready to outline the entire picture of experimental taxonomy in book form. To this end a taxonomic synopsis of the 85 species of the Madiinæ, based upon the principles of experimental taxonomy and embodying the results of the various lines of research, has been prepared by Dr. Keck. In order to give the historical setting and to show the application of the principles of experimental taxonomy in other groups of plants, Dr. Clausen has surveyed the literature of experimental investigations that have taxonomic applications. These deal with plants of many families from all parts of the world, and in many cases obvious taxonomic conclusions were not drawn. Mr. Hiesey has almost completed a manuscript on the transplant investigations; this is to contain not only the results to be gathered from Dr. Hall's experiments but also those obtained from the newer phase of investigations soon to be concluded.

### EVOLUTIONARY PATTERNS OF THE MADIINÆ

Much of the year has been spent in continuing the experiments on the Madiinæ, a subtribe of the Compositæ, necessary before the evolutionary patterns could be determined. An analysis of the existing species complexes within this group of plants well illustrates the fact that evolution has taken place in a variety of fashions. Some of these evolutionary patterns, taken from different groups within the Madiinæ, are pointed out below.



Transitions have been found between ecotypes and ecospecies. *Hemizonia angustifolia* DC. is differentiated into a northern ecotype, subsp. *typica*, and a southern one, subsp. *macrocephala* (Nutt.) Keck, each with 10 pairs of chromosomes. Only minor differences exist between the two, mainly in habit of growth, robustness of stem, size and congestion of heads, and slight differences in earliness. The first generation of their hybrid was highly fertile and intermediate in character. More than 1300 plants of an  $F_2$  population were grown, showing extreme segregation without reproducing either of the parents. Most of these offspring were healthy and vigorous, but careful measurements showed that 40 per cent of the  $F_2$  plants were below the lower limit of size of the parental ecotypes. Sixty-five per cent of these subnormals fell in the group just below the parents, but the remainder showed a gradual decline to tiny, although healthy, dwarfs less than 5 cm. in their largest dimension; these constituted about 1 per cent of the entire population. Very weak incompatibility barriers of this sort are certainly insufficient to warrant specific distinction and do not prevent the two ecotypes from mixing thoroughly where they meet in nature. Actually, one native ecotype population grades gradually into the other over a transitional zone some 100 km. in extent from north to south. These two taxonomic units appear to be in a transitional stage between the ecotype and the ecospecies. Such transitions are important because they indicate gradual steps in the evolution of specific differences.

In the section *Centromadia* of *Hemizonia*, characterized by species that may be readily crossed and having 9, 11, 12, and 13 pairs of chromosomes, slight differences in chromosome number may not constitute a barrier of even specific magnitude. Two ecotypes of *Hemizonia Parryi* Greene were crossed, a smooth prostrate one from the coast with 12 pairs of chromosomes, and a hairy erect one from the interior with 11 pairs of chromosomes. In spite of this chromosome difference, the  $F_1$  hybrid produced about 25,000 good akenes on six plants in an isolation plot. A small fraction of these were sown and produced about 2500  $F_2$  plants, all healthy and very vigorous, showing segregation for the habit and pubescence characters. So far as we know, this is the only established example of a chromosome difference between two naturally occurring ecotypes of one species, i.e., where hybridization between two such forms did not produce partial sterility in  $F_1$  and more or less unbalanced and weakened offspring in  $F_2$ .

In the hayfield tarweeds, *Hemizonia congesta* DC., emend. Bab. et Hall, it appears that the subspecies recognized by Babcock and Hall (1924) are actually species. All have the same chromosome number ( $n = 14$ ), they will intercross, and the hybrids show complete conjugation of the parental chromosomes; but the hybrids are highly sterile, with a fertility of only 2 to 10 per cent by open pollination in isolation plots, and, in addition, the second hybrid generation is decidedly weaker than cultures of the parental species. Here is the pattern of a species complex (cenospecies) consisting of closely related species (ecospecies) that remain apart through genetic incompatibilities although their chromosomes are entirely homologous. When genes and chromosomes of two of these species are exchanged in the hybrids, many of the sex cells and most of the resulting embryos and offspring are

nonviable or weak and unfit for competition. Under natural conditions, an exchange of genes can take place only rarely across the inherent barriers between these species. Only by using the technique of open pollination of the hybrids in small populations in isolation plots has it been possible to determine the degree of sterility and to grow sufficiently large  $F_2$  populations to reach these conclusions. As pointed out by Babcock and Hall, two of these species are further differentiated into seasonal ecotypes, and one of them also has developed a low maritime ecotype.

The three examples mentioned, from three different sections of the genus *Hemizonia*, indicate that the barriers between species are determined by the compatibility between the interchangeable genes in the chromosomes rather than by the number of chromosomes themselves or by their apparent homology as determined by their ability to conjugate. However, differences in chromosome number almost always produce a barrier, evidently because all life-important processes controlled by the genes within the chromosomes are so delicately balanced that any disturbance may upset the physiologic equilibrium. Following this concept, the section *Centromadia* of *Hemizonia* is characterized by less delicately balanced genic complements than any other group of Madiinæ.

It is found desirable to remove the section *Olocarpha* from *Hemizonia* and erect it as the genus *Holocarpha* (DC.) Greene, to include four species. The reason for this change is that an evolutionary gap exists between the two genera as evidenced by the following facts: (1) no *Holocarpha* is able to cross with any *Hemizonia*, whereas all species groups in the latter genus have now been interlinked with hybrids, even though many are sterile; (2) *Holocarpha* has 4 or 6 pairs of chromosomes as against 9 to 14 pairs in *Hemizonia*; (3) *Holocarpha* has an evolutionary pattern differing from that of *Hemizonia* in that speciation is proceeding mainly by way of segmental interchange or translocations between chromosomes (as in *Drosophila*), whereas in *Hemizonia* it is largely by genic differentiation; and (4) *Holocarpha* is morphologically distinct from *Hemizonia* by a series of very contrasting characters.

Cytological investigations have led to the discovery of two new species. One is a *Madia* from the northeastern corner of California, and has 24 pairs of chromosomes, the highest chromosome number of any of the Madiinæ. Apparently it arose through amphidiploidy by hybridization between *M. dissitiflora* (Nutt.) T. et G., a 16-chromosome species with which it has previously been confused, and *M. citriodora* Greene, an 8-chromosome species. It unites characters from both of these supposed parents, which are native in its area, and crossings between *dissitiflora* and *citriodora* are now being attempted in an effort to duplicate the new species. Amphidiploidy being a rare evolutionary pattern in the Madiinæ, this species is of special interest.

The other novelty is a tetraploid *Layia* ( $n = 16$ ) formerly interpreted as an autotetraploid *L. hieracioides* (DC.) H. et A. (normally  $n = 8$ ). Hybrids proved that the chromosomes of the tetraploid and the diploid were non-homologous; morphological characters have been discovered which will sepa-

rate the two, and the tetraploid species is now suspected of being an old amphidiploid between *L. hieracioides* and some unknown 8-chromosome species.

The different evolutionary patterns existing within the Madiinæ, such as have been pointed out, should caution anyone against generalizing his findings in one group of organisms to include the entire living world. Life seems to have so many ways of expressing and adjusting itself that probably only a limited number of its patterns have been uncovered.

#### MADIINÆ HYBRIDS

In addition to the hybrids listed in Year Book No. 33 (p. 175) and No. 34 (p. 204), an additional 61 have been grown. Seed of 11 more were produced but have not been sown as yet. This brings the total to above 200 successful hybrid combinations, largely interspecific, although not a few are intra-specific and two are truly intergeneric. Well beyond 300 different hybrid combinations, including the failures, have been attempted and about 75 species have been linked. Time and facilities have not yet permitted a detailed analysis of more than part of these important hybrid combinations.

The intergeneric hybrids are *Layia platyglossa* (F. et M.) Gray ( $n = 7$ )  $\times$  *Madia elegans* Don ( $n = 8$ ), a weak and sterile dwarf grown in 1934, and *Hemizonia arida* Keck et Clausen ( $n = 12$ )  $\times$  *Holozonia filipes* (H. et A.) Greene ( $n = 14$ ), a vigorous but sterile hybrid grown in 1937. The latter is easily the most remarkable Madiinæ hybrid yet produced, as it links the two main subdivisions of the subtribe. It is a hybrid between an annual and a perennial species, but not unique in this respect, as two more such hybrids, equally sterile, have been produced in the subtribe.

#### TRANSPLANT EXPERIMENTS (VARIED ENVIRONMENT INVESTIGATIONS)

A vigorous elimination of plants from low altitudes has taken place at the alpine transplant station at 3050 m. elevation. Plants native to the coastal region succumb rapidly, and those from middle altitudes die after several years of gradual weakening, leaving as survivors only plants native to the high Sierras or to high elevations of the Great Basin Plateau and those from northern latitudes. To check these results, the plants were replaced when they died, often several times. Frequently coastal plants die even at Mather station at 1400 m. elevation, although some survive with fair vigor.

With the present phase of the investigations on transplants approaching conclusion, new ones more closely associated with the general program of experimental taxonomy are being initiated. Some of these were referred to in Year Book No. 35 (pp. 212-213). Mr. Hiesey has developed a method for the quantitative determination of transpiration rates on individual leaves of plants growing in the gardens. The ultimate objective is to develop methods for comparative analyses of physiologic processes in plants representing different races of one species when grown in the same and in different environments, thus attempting to discover some of the intrinsic qualities determining the survival of plant races in their native surroundings.

Varied environment studies call for emphasis on analysis of racial differences. Considerable data and materials are now on hand illustrating racial



(ecotypical) differentiation in environments differing in altitude or latitude, and likewise on materials from maritime versus those from interior habitats, and on species of the circumpolar type having a very wide horizontal distribution. Several species have also developed spring and fall races adapted for different seasons in the same habitat. This type of adaptation characterizes a climate with marked seasonal differences like that of California. Genetical analysis has been made on some of these racial types within the annual *Madii*na, in *Zauschneria* and in *Potentilla*.

Some plant groups meet the requirements for environmental specialization with different ecospecies; others seem able to produce an equally effective specialization by means of ecotypes. Plant materials of the latter sort are more desirable for investigations on adaptational values that include genetic analysis than the former, because inherent genetic incompatibilities do not complicate the situation.

We have materials meeting these requirements in forms of *Potentilla glandulosa* Lindl. sens. lat., tested for many years in the transplant experiments. In California, this species is represented by specialized races almost continuously from the seacoast to arctic-alpine conditions at 3500 m. elevation in the Sierra Nevada. All forms are diploid with 7 pairs of chromosomes, and cross easily. Morphologically and physiologically very distinct altitudinal races are recognizable. Five years ago the self-fertile foothill race, from 800 m. elevation, was crossed with the self-sterile alpine race from 3100 m. These have been known as different species and are morphologically as distinct as any of the races in this complex. The foothill race does not survive at Timberline station, but the vigorous intermediate and self-fertile  $F_1$  survives there. An  $F_2$  population of about 800 vigorous individuals came to bloom this year at Stanford. The various segregated forms represent a variation similar to that found in certain habitats in nature. The alpine parent is the earlier of the two, but both are among the earliest races in culture. Some of the segregated hybrid forms were much earlier than either parental race, while others were later than any forms found in nature, there being a difference in earliness of more than two months among the offspring. The transgressive segregation for this physiologic character indicates that different sets of genes produce earliness in the two parental ecotypes. As soon as space is available at the mountain stations it is planned that the individuals of this unique hybrid swarm will be divided and transplanted for a study on climatic selection. Additional  $F_1$  hybrids between a race from the immediate coast, the foothill race, and the high-alpine race have been produced, but it takes two years to bring each generation to flower.

#### STUDIES ABROAD

Dr. Clausen spent three and a half months of the summer and fall of 1936 in Scandinavia, Finland, and England studying in herbaria and conferring with investigators interested in related subjects.

In company with Dr. Johs. Gröntved, of the University of Copenhagen, he made a botanical excursion into Swedish and Norwegian Lapland in order to study the arctic vegetation and to collect plant materials for a com-



parison with the arctic-alpine flora of the Harvey Monroe Hall Natural Area surrounding the Timberline transplant station in California. Seeds were collected on the trip to be grown for the study of racial differentiation in species of circumpolar distribution. The Californian races of some of these species were already included in the transplant experiments and their study requires a knowledge of at least some of the races native in other parts of the world.

Type collections of the *Madiinæ* in the Kew Herbarium were studied in order to identify them with the taxonomic units now recognizable from experiments. With an intimate knowledge of the natural races and ecotypes, one is sometimes able to determine the approximate vicinity in which types were collected by early explorers more than a century ago, even though the specimens carry such meager information as "North West Coast of America" or "California." At times it is possible to determine to which ecotype the type specimen belongs. The identities of the old species *Hemizonia multicaulis* Hook. et Arn. and *Sclerocarpus gracilis* J. E. Smith, hitherto unknown to California botanists, were found to be two common species of *Madiinæ* that have been passing under more recent names, but the original specific appellations are now to be restored.

#### OTHER INVESTIGATIONS

Systematic accounts of three additional sections of *Penstemon* have been brought to the point of publication by Dr. Keck. These studies of a large West American genus are in continuation of work started years ago, and follow conventional taxonomic lines rather than being of an experimental taxonomic nature.

#### DESERT INVESTIGATIONS

BY FORREST SHREVE, T. D. MALLERY, AND W. V. TURNAGE

The biological problems of the seven great desert regions of the world are partly universal, having common relations to all of them, and partly specific, having reference to each considered alone. The conditions of climate, soil, and the distribution of water in time and space vary through a wide range from those extremely unfavorable for organisms to those that are merely difficult. The phases of structure, function, and behavior which have adjusted plants to the various intensities of desert conditions are very much the same in all the deserts. Identical or closely similar features in anatomy, physiology, and adjustment to environment are found again and again in far-separated regions or in different continents. Some of the most fundamental desert problems arise among these universal features, and have to do with the ways in which evolutionary processes have molded the vegetative organs of plants, of whatever relationship, into successful desert patterns. The problems which are specific for each desert are those which concern its distinctive communities of plants, the relationships of the plants found there, the regions from which they have been derived, and the ancestral stocks from which they have descended.

Desert botanical investigation has been carried on intermittently for over 160 years. A small body of work has been done on the universal features

of desert plants and vegetation, chiefly by Europeans working in northern Africa and by Americans working in this country. On the specific features of the deserts, including the description of their vegetation and the study of their floras, a much greater amount of time and effort has been spent and a larger amount of work accomplished. The great difference between the degree of advancement in the universal and specific lines of desert work is due to the fact that the former requires laboratory facilities and long periods of residence in the desert, while the latter can be advanced by brief visits and rapidly moving expeditions.

During the history of the Desert Laboratory its efforts have been directed mainly toward study of the universal features exemplified in its vicinity. Such procedure promised at the outset the most important contribution to biology and the most effective use of the facilities of the laboratory. During the same period some comparative work was also done in other desert areas in America and abroad. Only recently has serious attention been given to the specific features of the North American deserts and to the systematic employment of field expeditions as a means of investigation. Expeditions to new regions give opportunity for study of the physiognomy and composition of the vegetation, observation of the local distribution of plant communities, and collection of material for investigation of the flora and microscopic study of plant anatomy. Such expeditions do not lend themselves to effective instrumentation or experimental work nor to gaining a familiarity with the seasonal or lifelong behavior of plants. The location and facilities of the Desert Laboratory make it possible, however, to do much to supplement the more superficial aspects of field work by cultivation of plants characteristic of distant localities and the study of their behavior under conditions not greatly different from their native ones.

For the past four years the work of the Desert Laboratory has centered around the study of the Sonoran Desert. Exploration has been conducted in all parts of the region, particularly in those that are remote from the already familiar surroundings of the laboratory. As a specific study of the region in which the laboratory is located, the Sonoran Desert project embraces work on vegetation, plant distribution, and flora from a viewpoint not taken in the earlier work. Problems of origin and history and of evolutionary change have been raised. The present status of these problems indicates that much help in their solution might be secured by a similar specific investigation of other desert regions in North America.

In the continuation of local investigations on physical conditions and plant behavior which were begun in the vicinity of the Desert Laboratory before the commencement of the Sonoran Desert project, a new significance is now manifested because of the bearing of the local work on the investigation of the larger area. This has been particularly true of the investigations on soil moisture and on highly local differences of temperature.

#### FIELD INVESTIGATIONS

The five-year program for exploration of the Sonoran Desert which was begun in 1933 has involved examination of all parts of the area and also

study of its geographic limits and of some of the types of vegetation into which it merges. Field excursions have been made during the past year in Sonora, Sinaloa, Arizona, and California.

In December 1936 Dr. Shreve spent two weeks in central and southern Sinaloa studying the ecological features of the thorn forest region and securing data on the distribution and relative abundance of plants also found in the southern part of the desert or represented there by closely related species. The semiarid thorn forest of Sinaloa has contributed to the Sonoran Desert a larger number of common and distinctive plant races than have been derived from any of the other plant formations by which it is bounded. Comparison of the vegetation in the southern and northern extremities of the Sonoran Desert reveals the presence in the former of a far greater number of distinct vegetative types of plants, adjusted to arid conditions in various ways, than are to be found in the north. The thorn forest, on the other hand, contains few representatives of certain genera which are important in the desert or have attained their greatest differentiation there (*Atriplex*, *Eriogonum*, *Encelia*, *Franseria*, and others).

In the spring of 1937 Dr. Shreve and Dr. Mallery traversed the valley of the Colorado River through western Arizona to Boulder Dam and southward through southern Nevada and the deserts of California. The principal objective of the trip was examination of the vegetation in the light of the characteristics which make it possible to distinguish the three types of desert, Sonoran, Mohave, and Great Basin, which meet in the region surrounding Needles, California. Throughout the Sonoran Desert its most favorable habitats, away from constant streams or springs, are characterized by small trees and numerous cacti. Of the trees the ironwood (*Olneya*), palo verde (*Cercidium*), and mesquite (*Prosopis*) reach the northern limit of their vegetational importance in the region just mentioned, and a large number of their smaller associates have the same geographical limit. The northernmost occurrence of typical assemblages of Sonoran Desert plants is in the immediate vicinity of the Colorado River between Searchlight Ferry and Boulder Dam. The northern limit of the giant cactus (*Carnegiea*) was found to be at the southern end of the Hualpai Mountains, where it grows with junipers, as it also does on part of its eastern limit in Sonora. The Joshua tree (*Yucca arborescens*) was followed for 150 miles in Arizona and its southern limit established in a region with climatic conditions very different from those at the northwestern limit of its occurrence in California. The opportunity on this trip to cross several times the boundary between the Sonoran and Mohave Deserts served to clarify the impressions of their differences gained from previous field work. The scarcity of small trees and cacti and the prevalence of small shrubs is the principal characteristic of the Mohave Desert.

During February and March Dr. Wiggins spent several weeks in the lower Colorado Valley, making collections of plants in the most poorly known part of the Sonoran Desert north of the International Boundary. The unusually cold and dry winter limited the fruitfulness of his trip, but he was able to secure a small collection and also many notes on the vegetation and the distribution of perennials. Dr. Wiggins visited the only known locality



for the fan palm (*Washingtonia filifera*) in Arizona, 125 miles from its nearest occurrence in California.

In May Dr. Mallery, Mr. Turnage, and Mr. Faurest Davis visited a little-known stretch of the Sonoran coast from Puerto Libertad south to Sargento and explored the northern coast of Tiburon Island. This is the largest island in the Gulf of California and, together with San Esteban and San Lorenzo Islands, forms the closest approach to land connection between Baja California and the mainland of Mexico. Notes on the vegetation and a small but interesting collection of plants were taken in this extremely arid region. Several plants were found which are common in Baja California but either had not been found before in Sonora or were known from a single locality. No additional localities for *Idria* were found. So many of the dominant plants of Baja California are endemic that every discovery of one of them in Sonora is of importance in the plant history of the region. Further exploration along the coast between Tiburon Island and Guaymas is needed.

A number of shorter routine field trips have been made in Arizona and Sonora for the purpose of securing rainfall and temperature data from various stations, some of which have been maintained since 1925 and some of which have been recently established for a short period for the determination of topographic influences on local rainfall.

An integral part of the investigation of the Sonoran Desert has been the cooperation by Dr. I. L. Wiggins, Curator of the Dudley Herbarium, at Stanford University, looking toward the preparation of a manual of the flora of that region. Through the sympathetic interest of Stanford University in this work Dr. Wiggins has been given nine months' leave, in the course of which he will visit Kew Gardens, London, the Gray Herbarium, Cambridge, and other taxonomic centers for consultation of type specimens of plants collected on early voyages and expeditions to the region in which he is interested.

For the past four years Mr. Howard Scott Gentry has been exploring the Mayo Valley, in southern Sonora, and making collections of plants on his own initiative in this botanically unknown region. On account of the close relation of Mr. Gentry's work to the exploration of the contiguous desert area, he has been invited to make use of the facilities of the Desert Laboratory with a view to the preparation of a paper on the geography and vegetation of the Mayo Valley, together with an annotated list of the plants collected there.

#### ENVIRONMENTAL CONDITIONS

Investigation of physical conditions on the grounds of the laboratory and at other localities in the Sonoran Desert has been continued and some new aspects of the study of air and soil temperature have been begun.

A thermograph and anemograph have been installed on the summit of Tumamoc Hill, 429 feet above the laboratory building and 764 feet above the floor of the Santa Cruz Valley. Continuous temperature records are now available for these three levels. The temperature inversion which has long been known to exist between the laboratory and the floor of the valley has now been found to extend to the top of Tumamoc Hill. The importance of inversion in connection with the local distribution of plants has been



emphasized by the records secured at the three levels during the exceptionally cold period of January 1937, and by the study of frost injury to native plants. At the laboratory during the past fifteen years there have been four winters without freezing temperature. In the winter of 1936-1937 there was a seasonal total of 588 hour-degrees below 32° F., with 185 hour-degrees on a single night with a minimum of 16° F. In the severe winter of 1912-1913 there was a seasonal total of 480 hour-degrees, with 214 on a single night and a minimum of 15° F. It is very significant for plants that records show no time when the temperature remained below 32° F. throughout the day. The records taken in the valley, at the base of the inversion layer, reveal the sharply different conditions to which plants in valleys and canyons are subjected. Each year severe freezes occur and the seasonal totals have ranged from 808 to 1900 hour-degrees below 32°. On the coldest night of January 1937, however, the valley record was 193 hour-degrees, with a minimum of 11° F., indicating that the inversion is not greatly magnified at the time of exceptional cold.

Observations on frost damage to native plants were made on all the field trips in the spring of 1937, and additional data were contributed by Mr. Jack Whitehead, of the Boyce Thompson Arboretum, Mr. A. L. Hinckley and Dr. R. R. Humphrey, of the Soil Conservation Service, Mr. H. S. Gentry, and a number of correspondents in outlying parts of the Sonoran Desert. No cases were observed in which plants were killed over large areas near their northern limit of distribution. Severe damage suffered by several species indicates that it is highly improbable that they will be able to extend their present distribution under prevailing climatic conditions. Among these plants are: *Bursera microphylla*, *Oleña tesota*, *Franseria ambrosioides*, *Encelia farinosa*, *Celtis pallida*, *Lemaireocereus Thurberi*, *Lophocereus Schottii*, *Jatropha cardiophylla*, and *Rathbunia alamosana*. A paper is in preparation which will summarize the temperature data for the past winter in southern Arizona and Sonora and the character and extent of the frost damage.

Determination of soil moisture at 8 depths to 6 feet has been continued and the records now cover a period of seven years. Ordinarily seasonal infiltration does not exceed 1 foot, and only once during the investigation have rainfall conditions been sufficiently favorable to cause infiltration to a depth of 4 feet. A more detailed sampling of the surface foot of this soil has been started, samples being taken every day or every other day during periods of sharp change in soil moisture. These samples reveal rapid penetration during a rain sufficient to raise the surface layer of soil to field capacity without increasing the moisture of the soil immediately below. The samples also show the rapid drying of the top inch of soil after rain and the slow drying of the layers below, which variously requires from 3 to 60 days.

Records of runoff for a 5-year period have been correlated with the rainfall intensity data shown by a tipping bucket rain gauge. Desert conditions cause marked seasonal changes in the capacity of the soil to absorb and hold rain water. In determining the infiltration capacity of the soil it is desirable to treat the rainfall intensity in 15-minute periods. Sharp differences in soil temperature and soil moisture preceding rain cause significant differences

in the infiltration capacity and field holding capacity in winter and in summer. Hence these factors are determined separately for the two seasons. For practical purposes the winter minimum infiltration capacity is 0.03 inch per 15 minutes and the maximum 0.06 inch. The summer minimum is 0.05 inch and the maximum 0.25 inch per 15 minutes. These figures apply to a level, bare, undisturbed clay soil. Further investigation is needed to reveal the quantitative nature of the factors causing these ranges in the infiltration capacity.

Continued investigation is being made of the temperature of the soil, which is of basic importance in relation to air temperature and to the moisture relations of the soil, as well as to the growth and functioning of roots, the germination of seeds, and the behavior of several classes of animals. During the year thermocouples have been placed in the soil at depths which experience no daily variation, and thermographs are being used for the superficial soil layers. Regular readings are now being secured at the surface, at 3 inches, 12 inches, 2 feet, 3 feet, 6 feet, and 12 feet. Considerable effort has been expended in securing reliable surface readings, which involve a high range of temperatures during the dry summer months. In June 1937 the daily surface soil temperature was from 40° to 50° F. higher than the air temperature, and reached its annual maximum at 165° F. A study is being made of the influences which determine the fluctuations in surface soil temperature, and of their relation to the temperature of the lowest levels of the atmosphere. The work has its principal biological importance in the physiological effects of high temperatures, especially in conjunction with the water relations of plants, and in its relation to nocturnal temperature inversion, which results in very high daily temperature ranges near the soil surface.

The investigation of rainfall has been continued with reference to its distribution throughout the Sonoran Desert, the influence on it which is due to smaller or larger mountain masses, and the meteorological conditions which control its seasonal distribution.

At 10 long-period stations records of rainfall have been taken for 9 to 12 years, and at 22 additional stations for 5 years. Several voluntary assistants keep record of the time and amount of each rain storm at their particular station. The Mexican Meteorological Service has been very helpful in the exchange of data and has made it possible to chart the distribution of rainfall for most of the Sonoran Desert. The lowest annual averages in the series are 3.70 inches at Cirio Point on the Gulf coast of Sonora, and 4.10 inches at the Lechuguilla station in southern Yuma County, Arizona. The highest desert station has an annual average of 16.20 inches, while the average at 7875 feet on the forested summit of the Santa Catalina Mountains is 33.30 inches. Wide variations are found in the summer rainfall, the extremes at Tule Tank, Arizona, being 0.00 to 6.40 inches, and at Cirio Point, Sonora, 0.40 to 11.20 inches.

Most of the long-period rain-gauge stations are located on the gentle slopes of intermont plains, and while there is some tendency toward higher amounts of precipitation at the higher elevations, the correlation is not unailing. In an attempt to determine the relationship between rainfall and elevation three series of gauges have been placed on the northeast slopes of three different

mountain ranges in southern Arizona at altitudinal intervals of 500 feet. Two of the mountain ranges are relatively low, the highest rising only 5200 feet, and on these, little if any influence of elevation on rainfall has been found. On the slope of the highest range, which reaches 9000 feet, there has been found a steady gradient of increasing rainfall with increasing elevation. A more or less precipitous land-mass rise of over 3000 feet above the surrounding plain is necessary before an altitudinal rainfall gradient is established. These findings explain the existence of desert vegetation on small mountain ranges at altitudes which are forested on the large ranges.

#### BEHAVIOR OF DESERT PLANTS

Work begun three years ago on germination, character of seedling, and early life history of desert perennials has been continued, and during the past year a much larger series of plants has been under observation. The aim of the work is to learn as much as possible about the critical stage in the life of desert plants which lies between the maturing of the seed and the establishment of a new individual. The material used has been representative of a wide range of vegetative forms which constitute important elements in the vegetation of the Sonoran Desert.

It has been definitely established that the seeds of all the large perennials, all the cacti, and most of the shrubs germinate at soil temperatures between 80° and 95° F. This is the prevailing range during the summer rainy season. Several species of *Franseria* and *Encelia* germinate only at temperatures ranging from 60° to 75° F., corresponding to the natural soil temperature conditions during the winter rainy season. In the majority of woody perennials all seeds germinate at once under favorable temperature conditions. In a few species it has been found that some seeds germinate at once, others in the following year, and still others in the third year. The rate of growth of seedlings and the size attained in the first season vary greatly, as do also the relative development of root and shoot.

The form of the seed leaves and of the successive leaves in the early life of the seedling is often widely different from that in the mature plant, and is of interest in confirming the relationship of the plant as well as in recapitulating the steps by which the xeric adult form has been developed. The leaf history is of particular interest in the trees which have green leafless stems in full-grown individuals. A series of drawings is being made as a record for each species.

Seedlings one year old are transplanted into the open and given some protection and watering for a few months. After becoming established they are subject to the normal climatic fluctuations of the Tucson region, and their reaction to periods of drought and cold is noted. During the unusually cold period in January 1937 many of the young plants from Baja California and southern Sonora perished. Three species of southern range survived, however, which gives some ground for maintaining that low winter temperatures are not a universal impediment to the northward migration of the woody plants of the southern part of the Sonoran Desert.

In conjunction with the transplant studies which are being carried on by the Experimental Taxonomy section at the Central Laboratory of the Di-



vision, consideration is being given to the development of methods for measuring certain physiological characteristics of the transplants. The osmotic concentration of the expressed sap is considered by some workers to be a measure of the plant's physiological response to its environment. For the past two growing seasons Dr. Mallery, with the cooperation of Dr. Keck and Mr. Hiesey, has made a preliminary test of the cryoscopic method of determining plant sap concentrations, using transplant materials. The purpose of this investigation was to compare the response of the same form of a given species growing in different habitats and of different forms of a given species growing in the same habitat, as indicated by the seasonal changes in the sap concentration. In this way it was thought that a measure of the physiological stability of each form and species of plant under consideration might be obtained.

With a great accumulation of taxonomic and cytogenetic data as a background and with the possibility of studying the same individual in different habitats by clone division, the established transplant material was ideal for this investigation. *Artemisia vulgaris*, *A. tridentata*, and *Achillea millefolium* proved to be the most satisfactory species to work with from the standpoint of availability and habit of growth.

For the species studied it was found that variations in the environment of individuals of a given form or race are reflected in the freezing-point depressions obtained for the respective individuals. This was clearly brought out by the sap concentration values obtained for the plants growing in the moist and dry sun and shade plots in which the same individuals are grown in each of the four situations, thus eliminating the possibility of individual variation. Leaf material gathered from *Artemisia vulgaris* and *A. tridentata* growing in their native habitats gave freezing-point depression values consistently correlated with the degree of aridity present. In every case the sap concentration gradient could be predicted on the basis of the uniformity of moisture conditions at the various sampling stations.

The data obtained for different forms of the same species growing in the same habitat indicated that each has a degree of physiological individuality or stability. For example, the Pismo form and the Santa Barbara form of *Artemisia vulgaris* growing side by side in the introduction garden at Stanford University yielded different plant sap freezing depression values. The Santa Barbara form gave consistently lower values. These results correlate well with the survival phenomena for these two coastal species when they are transplanted to higher elevations. At the Mather transplant station the Pismo form survives, while the Santa Barbara form, with lower sap concentrations, perishes. It is possible that the higher values in the Pismo form enable it to withstand freezing weather more successfully.

The preliminary applications of the cryoscopic method of studying changes in plant sap concentration to the interpretation of transplant phenomena show that while the method places the broader ecological concepts on a somewhat more scientific basis, it is not sufficiently critical to meet the needs of the biological chemist or the cytogeneticist, whose materials should be produced under more accurately controlled conditions.



## ECOLOGY

ADAPTATION AND ORIGIN, BY F. E. CLEMENTS, F. L. LONG, AND E. V. MARTIN

For the purpose of measuring single direct factors or factor complexes under which adaptation is occurring, batteries of phytometers on the largest scale yet employed have been utilized throughout the three seasons, during the summer in the transplant gardens on Pikes Peak and during fall-winter and winter-spring in the adaptation gardens at Santa Barbara. In addition, both sunflower and lupine phytometers have proved of much value as representing the functional behavior of experimental plants, which could not be readily transferred to containers.

The installations at Pikes Peak comprised a series of batteries in each of the three climaxes, viz., plains grassland, montane forest, and alpine tundra. The first contains three experimental gardens, the second, five, and the third, seven. Each battery consisted of 12 sealed phytometers and 20 free ones, 10 in the soil of the habitat and 10 in a soil uniform for all habitats and containers. The measurements taken included transpiration, rate of growth, height and diameter of stem, leaf area, wet and dry weight, and water requirement. For the climatic series, the transpiration values in the sun by relative units were 72 for the plains, 43 for the montane, and 8 for the alpine zone, while the corresponding water requirements were 485, 416, and 249 gm. For 20 per cent light in the lath houses, the relative losses were respectively 34, 23, and 3. In the edaphic series at the plains garden, with sun, 20, and 10 per cent light, the relative transpiration was 72, 34, and 27; at the montane with sun, 20, 10, and 5 per cent light, 43, 23, 13, and 6; while at the alpine they were 77, 27, and 30, temperature overruling light in the deeper shade.

In the length-of-day tents at Santa Barbara, sunflower phytometers were employed to measure the conditions that determine time of flowering, which regularly proceeds from the long-day of 14 hours to the mid-day of 9 and the short-day of 5 hours. The maximum height and diameter were found in the long-day tent and the minimum in the short-day. The transpiration ratios were respectively 55, 38, and 13, the dry matter 25, 13, and 2 gm., and the water requirement 214, 299, and 651 gm. As an experimental species, wheat yielded similar results, though the decrease in dry weight in the short-day was much less. In the three kinds of soil pits, the values decreased in every case from garden loam to clay and sand; height and diameter were respectively 49 and 0.9, 31 and 0.5, 17 and 0.4 cm., leaf areas 679, 261, and 90 cm.<sup>2</sup>, and the dry weights 10, 3, and 1 gm. The transpiration ratios were 34, 13, and 5, and the water requirements 349, 358, and 388 gm. The 12 adapted species grown to maturity gave comparable responses, but the dry weights for sand were naturally far lower relatively, owing to the much longer exposure to dry soil. With added nutrients, the dry weight was increased approximately threefold for both phytometers and experimental plants, and nearly as much again when the fertilizer was doubled.

At Santa Barbara also, a comprehensive series of sealed and free phytometers was installed to analyze the functional and structural responses to stable dunes (shelter garden) and mobile dunes (ridge garden) along the seashore and to compare them with the results obtained in the main garden

a few miles inland. The free phytometers were grown in soil pits, each garden having a pit of soil from the other two and in addition three pits of its own soil, the control receiving rain alone, the second being watered, and the third both watered and fertilized. Sunflower phytometers were grown in these from October to January and a second series from February to May, as was a set of lupine phytometers likewise. As with previous installations, the results differ to some extent between the series, owing to opposite gradients of light and heat for the two seasons.

In general, stem height proves to be the best integrator of growth conditions, in the three soils as well as in the corresponding gardens. Stature decreases consistently from garden loam to stable and mobile sand in practically all seven replications for the years 1934-1937, as it does likewise though to a smaller degree from the main garden to the shelter and ridge gardens. Transpiration and dry weight behave in the same fashion; the former varies as 50:20:2 in the three soils, loam to sand, and as 6:5:4 for loam in main, shelter, and ridge gardens. In general, the water requirement falls from mobile to stable sand to loam and from ridge to shelter to main garden.

Lupine phytometers are in accord as to the reduction of stature, transpiration, and dry weight from loam to mobile sand, but as to gardens the dry weight was highest on the ridge and lowest in the main garden, a departure probably to be explained by the fact that this is a typical dune species. However, when the whole plant was exposed to dune conditions, as in the free series, lupines gave values of 44, 24, and 4 gm. from loam in the main garden to mobile sand on the ridge. When flat pans were placed at such a depth in the sand as to prevent water from sinking below the root level, the stature was a fourth as great and the dry weight thrice greater for both sands than in the control. The addition of fertilizer to the loam had but little effect, while in both stable and mobile sand it increased growth several times.

The behavior of more than a hundred adapted species was in close agreement with the phytometers as to stature, leaf area, dry weight, size and number of flowers, etc. As the above results show, soil factors are of primary importance in the dunes, while aerial ones are much less so, the ratio between them in case of height being about 4:1. Of the major soil factors, nutrients usually produce a more marked effect than water, owing to the fact that the latter quickly passes beyond the root layer so that the holard is usually around 3 per cent. However, the pan results show that water may be almost equally effective, and it is probable that fertilizer acts chiefly by promoting a better root system, which is able to draw water from a much larger mass of soil.

For a number of reasons, the grass genus *Stipa* has been selected to set the pattern in the synthetic study of the simultaneous evolution of community and species. Of all genera of climax dominants, *Stipa* is perhaps without a peer in importance and extent, not only as to the number of species, subspecies, and forms, but also as having a dominant rôle in climax associations the world over. As the most highly specialized of grasses, it has undergone rapid and comprehensive evolution, which is reflected in the differentiation

of grassland on all the continents. Originating in the circumpolar region of the northern hemisphere, it has been driven southward by climatic shifts; it has crossed the equator at times of high continental emergence and has spread out over Australia, Africa, and South America far into Patagonia.

The regional species of *Stipa* have been grown extensively in the climatic and edaphic transplant gardens at the Alpine Laboratory, and conversions within phylads, such as *capillata-comata-spartea* and *viridula-robusta-minor*, have been made repeatedly. Southern species that do not survive Colorado winters have been subjected to modification at Santa Barbara, as with the phylad *leucotricha-pulchra-eminens*, and the other conversions have been duplicated there also. Somewhat more than 50 species have been grown for a decade in a special garden devoted to the study of variation, life histories, selfing, and suitability for forage production and erosion control, and a dozen or more of these have been subjected, as divisions of a single plant, to gradients of light and water, as well as to the action of the two dune complexes.

The extensive collections in the U. S. National Herbarium have been studied in detail with especial reference to the original stocks and their modification as they were dispersed throughout the globe by virtue of climatic compulsion. The major stocks are largely identical for Eurasia and North America, and several of these continue into South America with the evolution of a host of new forms. The African species are for the most part those of Europe or derivatives of them, while the Australian ones, though evidently derived from Asiatic ancestors, reflect a longer break in land connections. It seems probable that the line of continuous descent that is represented by *capillata* of Eurasia, *comata* of the Great Plains, *pulchra* of California, *leucotricha* and *mucronata* of Texas and Mexico, and *neesiana* of Central and South America is unsurpassed as an example of evolutionary migration.

CLIMATE, CLIMAX, AND SUCCESSION, BY F. E. CLEMENTS  
AND E. S. CLEMENTS

The comprehensive application of dynamic ecology to the various cooperative projects in conservation that deal with the plant cover has been of great value in testing and confirming the basic principles. It has also served to refine and extend the many quantitative methods employed and to focus them more sharply upon practical values without sacrificing scientific objectives. Of equal importance is the fact that hundreds of demonstration and research projects have provided trials of principles and methods over the widest range of climatic and crop regions, as well as of extreme weather conditions during the growing season. As a consequence, it has become evident that conservation is concerned with a unified complex of processes and that the ecological attack upon these represents the necessary combination of analysis and synthesis. This applies equally well to the correlation of re-



search and practice, since progress in the latter depends upon comparative installations that are of the essence of investigation. This may be illustrated by the new method of reenforcing pasture terraces by means of shallow trenches to hold falling rain equally over the intervals; in this, tests of size, depth, and spacing of trenches are carried out on the ground by means of artificial rain of known intensity, produced by the so-called "rain-maker."

One of the leading concepts of modern ecology is that of indicator vegetation, in which the climax community integrates the influence of a particular climate, thus in effect smoothing the curve of annual departures in rainfall and temperature. Other more localized communities indicate conditions of soil and moisture, and a host of others recur wherever man has been active in disturbing cover and soil. In short, the intricate mosaic of vegetation can be translated into everyday terms by means of the proper ecological keys. This has been done in large measure for more than a decade (*Plant indicators*, 1920), but it has required drought on an unprecedented scale to give currency and effectiveness to the ideas involved.

The most significant and far-reaching application of the indicator method has recently been made in connection with the economic and social problems of the Great Plains. In an initial study at long range, it was assumed that the short-grass so widespread in the region indicated a climate too dry for farming and suited only to grazing. Hence, it was concluded that approximately three-quarters of a million people should be moved out of the region and the abandoned farms returned to grass. Fortunately, the premise is entirely erroneous and the conclusions are correspondingly mistaken. The true climax of the Great Plains is mixed prairie, a mixture of medium and short grasses, in which the latter play a minor part. With the cumulative overgrazing of the past half-century, the mid-grasses have been largely removed except in small protected areas and the short-grasses have profited by this to cover pasture and range with a low sod. In dry years especially, this simulates a climax and seems to be an indicator of an arid climate. However, the ecological evidence is conclusive against this assumption. Not only is mixed prairie to be found wherever protection against grazing has existed, but it can be converted into short-grass by overgrazing and again restored by fencing out stock. Competition experiments have confirmed this in detail, and equally satisfactory are the early accounts and photographs which prove that the original vegetation was mixed prairie. Both from the rainfall relations and from the abundance of wheat grass in it, this community is an indicator of the fitness of the region in general for dry farming.

This has further been substantiated by the crop production at the stations for dry-land agriculture during the past ten years. Moreover, the type of crop to be preferred is suggested by the occurrence of wheat grass (*Agropyrum Smithi*) as a dominant of the prairie. It occurs over most of the region, dropping out only in the southern part. It is not only a grass of the cooler climates, but it also has a water requirement higher than that of its associates and prefers finer soils with more organic matter. In addition, it is a close relative of wheat, as the name indicates. Hence, it is an indicator



not merely of cropping possibilities, but likewise of the suitability of a particular crop, namely, wheat.

Intensive study and experiment in the mixed prairie as a part of soil conservation projects dealing with drought, grazing, and recovery on abandoned farms have verified its ecological indications and extended its area of utilization. It had been shown earlier that the outcome of any one of these processes could be definitely predicted, since the response of each grass dominant was regularly the same. Under drought, the mid-grasses suffer more than the short-grasses and yield to them visibly; bunch grasses are less resistant than the sod-forming wheat grass. The low grama (*Bouteloua gracilis*) ultimately gives way to buffalo grass (*Buchloe dactyloides*), to which its stolon gives much the same advantage in competition that the rhizome does to wheat grass. Since competition is again involved, the course of events under overgrazing is nearly identical. The sod-former *Agropyrum* prospers at the cost of such bunch grasses as *Stipa*, *Koeleria*, and *Sporobolus*. *Agropyrum* then yields to the short-grasses, and of these buffalo grass gradually wins over grama, partly by virtue of a denser sod but chiefly through rapid propagation by means of stolons. Throughout the process, the less palatable plants or forbs increase at the expense of the grasses as they are weakened by grazing, until in the extreme condition a cover of hardy buffalo grass may largely or wholly be replaced by one of weeds, which is valueless for forage or for erosion control.

The course of recovery in abandoned fields can be forecast in accordance with the indications of the cover in relation to soil and type of cultivation. When cultivation is shallow, grasses, especially sod-forming ones, may spring up directly from underground buds, or much less frequently from buried seeds. In general, however, they can regenerate only from seeds blown into the area, and the kind and abundance of these will be determined in part by the original composition and in part by the kind and amount of disturbance that has operated upon it. Since abandoned fields are nearly always grazed from the first, the course of succession as modified and retarded by this process must also be taken into account.

A recent and novel extension of the indicator method with great practical possibilities has been suggested by the study of grasshopper outbreaks. In southern California, the five instars of the warrior grasshopper (*Camnula pellucida*) feed in nature upon such forbs as *Erodium*, *Medicago*, and *Trifolium*. However, these have dried up about the time the winged adults appear, and the latter are forced to turn to the perennial bunch grasses, *Stipa*, *Poa*, *Koeleria*, etc., which remain green much longer. The consequence is that they deposit their eggs in such communities, which thus serve as indicators of egg sites. The use of exclosures and quadrates renders possible quantitative determinations of infestation in terms of egg pods and sites, and thus permits forecasts as to the probability of a serious outbreak the following year.

The ecological synthesis of factors, processes, and methods of production and control, especially under conditions of drought and dust storms, has been embodied in a fifty-page memorandum to the Great Plains Committee, by which it has been adopted as the basis for the solution of the human problems concerned in rehabilitation and conservation in the West.

## PALEOBOTANY

BY RALPH W. CHANEY

Studies of Cenozoic plants have continued along the lines described in previous reports and may be summarized as follows.

R. W. CHANEY—During the field season of 1936 studies were carried on in Alaska which throw light on the conditions under which plants are deposited and preserved in the fossil record. In the volcanic ash which fell on Kodiak Island during the eruption of Mount Katmai in 1912, and which has accumulated in lake basins on the island, there were found the remains of leaves and cones. These represent species which still live on the borders of the lakes. There are indications that most of the plant remains were deposited immediately after the fall of volcanic ash, and that volcanic sediments subsequently washed into the lakes are not a suitable medium for the preservation of leaves. Studies of the conditions of plant accumulation in the vicinity of Fairbanks show a still different mode of preservation. At this high latitude, ground ice fills the soil up to within a few feet of the surface. Pleistocene and Recent organisms buried in the valley sediments become frozen and remain well preserved. Since such a mode of preservation depends largely upon sustained low temperatures, it is doubtful whether it has been of any great importance over long periods of geologic time, during which temperature changes have been of regular occurrence.

Such studies of geologically late plant-bearing deposits offer significant evidence as to the mode of accumulation of fossil plants in the older rocks of western America. Many of these, such as the Clarno formation, the Bridge Creek shale, and the Florissant lake beds, were deposited through the action of volcanoes. A somewhat different mode of emplacement was involved in the Deschutes formation which has recently been studied in eastern Oregon. This contains the remains of a forest which lived in a valley on the side of a volcanic peak during the Pliocene. Mud flows have buried the leaves of aspens and other trees, and they have been preserved as impressions in the Deschutes tuff.

D. AXELROD—Extensive collecting of the Miocene Tehachapi and Puente floras of southern California shows that the Miocene vegetation of this region was of a warmer type than that recorded from beds of this age in northern California and Oregon. This is consistent with the difference of latitude, and is evidence of the lack of "cosmopolitan" conditions during the Miocene on the west coast.

E. DORF—Extensive collections have been made from the Cretaceous of the Rocky Mountain region. An analysis of the field and floral evidence is throwing much light on the stratigraphy of this region. Further studies in progress are expected to add to our knowledge of the centers of distribution of Mesozoic angiosperms.

H. D. MACGINITIE—The Florissant flora is one of the largest Tertiary assemblages in North America. Field and laboratory studies have been carried on here within the past year by Dr. MacGinitie and will be continued during the coming season. Part of the financial support for this work has been contributed by Mr. Childs Frick, of the American Museum of Natural History.

## CLIMATOLOGICAL RESEARCH

By A. E. DOUGLASS

## FUNDAMENTAL STUDIES

During the past year a detailed study has been made by Mr. Edmund Schulman upon the relation between rainfall and ring growth in some 50 Monterey pines from Carmel and Monterey, California. The site of each was carefully selected so that deficiency of precipitation should be promptly felt by the trees; thus thin soil, steep slopes, and some isolation from neighboring trees emphasized the deficiency.

Under these conditions the trees show excellent cross-dating and it is possible to identify certain "double" rings. Upon recognizing these, the correlation coefficient between rainfall and annual growth is  $0.75 \pm 0.05$ . Mr. Schulman noted three types of doubles: (1) the "fuzzy" type, well known in Arizona trees, which is apparently formed in the spring; (2) a type due to September-October rains (noted by MacDougal); and (3) very rarely a faint extra ring or a slight added growth of late-wood caused by a November rain.

A group of some 50 cores from pine trees near Macon, Georgia, collected by Mr. Gordon Willey, has been examined and the existence of cross-dating confirmed.

Dr. Glock had his attention directed to an uncommonly large western juniper in the high Sierra Nevada by Mr. C. K. Bennett, of Hillsborough, California. Three methods of age estimation gave an average of 3000 years. A study of the time of ring formation, including trees from the lower forest border up almost to timber line, showed clearly that, for 1936 at least, the trees made their growth early in the season. At an elevation of 8500 feet growth was in progress while the snow was leaving the ground. At the lower forest border growth had been completed by the first week in July. These studies have an important bearing on the relative influence of moisture and temperature on tree growth, since moisture is most abundant immediately after the winter rainy season in the Sierra Nevada. The probable age of the juniper and the time of ring formation have been described by Dr. Glock in *Madroño*, March 1937. He is also carrying out a promising series of correlations between details of tree-ring growth and month-to-month distribution of rainfall at Prescott, Arizona. For such correlations the development of method is a necessary part of the procedure and to this end the method of "trend coefficient" (Year Book No. 32, p. 209) has been extended and refined.

## CYCLES AND THE CYCLOGRAPH

In an attempt to bring the cyclograph into more general use, it was reconstructed out of metal in 1936 and so designed as to include various convenient rearrangements of the parts. The mechanical work of precision was done by Mr. Burton Stuart, of the Physics Laboratory shops of Stanford University. In its new form the instrument included an automatic focusing device and a convenient scale-reading arrangement connected directly with the sprocket chain to which the mirrors are attached. A comparator frame capable of carrying ten cycleplots, that is, ten different sequences of data



prepared for analysis, was made by Mr. C. G. Keenan in Tucson, Arizona. It is operated by a handle convenient to the observer, who may transfer from one cycleplot to another in one or two seconds.

The new cyclograph was exhibited in Washington, D. C., April 23, 24, and 25, 1937 in a third cycle conference attended by a group of investigators interested in cycle analysis. The group included astronomers interested in the analysis of variable-star periods and in cycles of solar activity; members of the Department of Terrestrial Magnetism of the Carnegie Institution, who are doing a very important work on reception, measurement, and analysis of solar radiation of different kinds, as well as on cosmic rays; astronomers and meteorologists interested in the analysis of solar and terrestrial cycles; economic meteorologists interested in the possible influence of the sun on weather and crops; and students of business activity. In these various groups there was general recognition of the utility and great speed of the cyclograph in preliminary surveys of data.

This conference brought out the fact that it is difficult for one who is accustomed to periods which are permanent and exact, to realize that climatic and solar cycles are not permanent or exact and yet have important characters that can readily be investigated by the cyclograph. It is in just such cases that this instrument shows its unique power to resolve cyclic repetitions. It is hoped that a clarification of the term "cycle" in conjunction with more general use of the cyclograph will facilitate further investigation into the complexities of climatic and solar variations.

Great assistance was rendered by Mr. Edmund Schulman both during the construction of the new cyclograph and during its demonstration in Washington, D. C.

#### SOLAR ROTATION TESTS

After a conference with Dr. J. Bartels at Palo Alto, California, in August 1935, it appeared worth while to see how the cyclograph would handle solar rotation indications in the magnetic character figure C which he had used in his summation dial. The daily magnetic data were analyzed on October 31, 1935, and at once the striking persistence of solar rotation near 27.0 days was observed. This was especially evident in the years 1930 and 1932-1934, and even later. It was also seen at once that there was long-continued activity in opposite solar longitudes and that in these years the six-months maxima alternated between these opposite longitudes. This result was supported by two evident secondary periods appearing at 25 and 29 days, due to apparently spurious periodic effects between these alternating six-months maxima.

The alternating maxima have been made easily visible by means of the ordinary physiographic relief model on cardboard prepared in December 1935 by Dr. Glock (Publication No. 289, vol. III, pl. 19C). The first card carries rotations 1, 2, and 3; the second carries rotations 2, 3, and 4; and so on through the years 1932, 1933, and 1934. The cards are mounted at equal intervals, their higher parts illuminated, and the whole viewed through rayon. By this method the alternating maxima appear distinctly.

Upon testing sunspot occurrences and other data in similar manner, very striking results were obtained as to solar rotation in sunspots, calcium



floculi, ultraviolet light, and other solar phenomena. Clear evidence of rotations could not be detected in Abbot's solar radiation data. Finally, tests of Arizona rainfall for 101 stations gave a prominent cycle (1932-1934) at 28.5 days and a less important one near 27.0 days. Considerable extension of these tests to other regions and other data has given as yet indeterminate results.

#### RING PHOTOGRAPHY

A Central Pueblo (Colorado plateau) chronology, 1925 years long, has been photographed in excellent fashion by Mr. H. F. Davis. Recently piñon and juniper have been included. Mr. Davis has done important work in preparing the specimens and getting effective photographs. He has also made great advance in technique in the photography of charcoal rings by the use of collodion and of cellulose acetate. This technique is important because a large part of the early ring collections are in charcoal.

#### COOPERATIVE ARRANGEMENT

The cooperative arrangement between the Carnegie Institution of Washington and the University of Arizona remains as during the previous year, and the same courtesy of rooms and aid has been afforded by the Desert Laboratory of the Carnegie Institution at Tucson.

# DEPARTMENT OF TERRESTRIAL MAGNETISM <sup>1</sup>

JOHN A. FLEMING, DIRECTOR

O. H. GISH, ASSISTANT DIRECTOR

## SUMMARY

During the report-year (July 1, 1936 to June 30, 1937) the program of the Department has been devoted not only to experimental investigation, but also to the coordination and integration of isolated researches that the inferences of each may be more broadly interpreted. Such a program cannot be consummated within a limited period, so that reports of successive years must bear similarities outlining the general progress and application of experimental fact as it is revealed. During the past year the common goal and unity of the several branches of research have been admirably demonstrated.

Thus the association of a special type of magnetic disturbance and sharp fade-outs of high-frequency radio-wave reflections with bright eruptions in the solar chromosphere was conclusively proved during the past report-year by the work of this Department in cooperation with Mount Wilson Observatory and other organizations. This constitutes the major advance in terrestrial-magnetic research in recent years. These effects are propagated from the Sun to the Earth with the velocity of light. The active agent is believed to be ultra-violet light originating in the solar eruption, which produces sudden and intense electrification of the Earth's upper atmosphere. Previously the view was generally accepted that no *direct* correspondence exists between observable solar and terrestrial-magnetic phenomena. These new effects serve to discriminate between various theories of terrestrial-magnetic changes and supply evidence on the electrical processes taking place in the ionosphere. The discovery that the phenomena of radio fade-outs are related to a magnetic effect of the diurnal-variation type is a definite advance toward the ultimate objective of the ionospheric investigations. The determination of the heights at which this effect occurs was made possible through the program of automatic recording at the observatories. The high ionization produced below the lower *E*-region of the ionosphere by bright chromospheric eruptions apparently causes radio-echo disappearance through absorption in this region of high collisional frequency. The production of this high ionization is the necessary condition for the magnetic disturbance of the diurnal-variation type and its recognition is a definite step toward understanding of magnetic perturbations.

Continued observation shows close relation between the ionization of the outer atmosphere and sunspot-activity. The enormous changes of ionization which have occurred, as shown by the ionospheric records at Huancaayo and Watheroo, with advancing sunspot-number indicate that this relation may be one of the closest of terrestrial and solar relationships. That the change in different regions of the ionosphere is found to be materially different has particular significance to problems of terrestrial magnetism.

With advanced technique and improved equipment, information concerning the nature of the electrified particles in the lower ionosphere has been ob-

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tained. It is now possible to set a limiting ratio between the number of ions of atomic and molecular size by experimental observation.

An aspect of correlation of terrestrial-magnetic with cosmic-ray phenomena was shown by the recent discovery, from cosmic-ray investigations at the Department, of the effect of a magnetic storm upon cosmic-ray intensities at widely separated stations. This discovery may prove useful in furthering knowledge of the energy-distribution of cosmic rays on the one hand, and on the other may provide valuable evidence regarding the location of the current-system responsible for magnetic storms. It may also point the way, in some known or unsuspected terrestrial-magnetic phenomenon, to the cause of the solar diurnal variation in cosmic-ray intensity.

The effect of the Moon on variations of the Earth's magnetism was beautifully demonstrated in the further discussion of the data accumulated at Huancayo from 1922 to 1934. The lunar influence there is so great that it actually may be noted in a single day's record.

Attention was also directed to the origin of the Earth's permanent magnetic field. In contrast with the prevailing belief that the Earth's interior is at a high temperature—so high that ferromagnetism cannot exist at great depths unless the Curie-point temperature rises rapidly with increase in pressure—a hypothesis was proposed to account for lower temperatures at great depths, attributable to a different mode of cooling for the Earth, which may permit the interior to be ferromagnetic.

Preliminary experiments were made on electromagnetic testing of rock-samples to determine direction and intensity of their residual magnetization. Primarily intended for application to ocean-bottom core-samples obtained with the apparatus developed at the Geophysical Laboratory, this new method will permit magnetic examination of many other rocks. Such information may supply data on the condition of the Earth's magnetic field in past geological ages and may furnish other facts important to geology.

Continuous records of the rate of formation of the fast-moving ions in the atmosphere have provided evidence pointing to the existence of an unsuspected factor in the atmosphere, tending to control its electric conductivity. This factor is the water-vapor in the atmosphere, which appears to combine with the large or slow-moving ions, thus making them more efficient in removing the small or fast-moving ions.

Continuing the laboratory-investigations of magnetism, as relating to the basic structure and properties of matter, further measurements on the "new" physical force, which serves to bind together the protons and neutrons making up the nuclei of all atoms, confirmed and extended the first observations and measurements announced in the report of last year. This force has long been inferred to exist as a universal property of matter, ranking with gravitation and electromagnetic forces in its importance to the structure of the cosmos. Its direct observation and measurement last year using the Department's high-voltage equipment, now strikingly confirmed by the new measurements, is an achievement of lasting importance. Other measurements in connection with these investigations, relating to neutron-intensities, appear separately important to biochemical, genetic, and cancer researches, and exemplify the wide significance and application of such fundamental

studies. Precise measurements on the most familiar group of nuclear transmutations—those of lithium—demonstrate the existence of an unexpected four-body process, and give hope of a future experimental demonstration of the existence of the hypothetical particle called the neutrino, which has been assumed to exist because of certain crucial difficulties in the understanding of transmutation-processes involving electron (beta-ray) emission.

The construction of a long-planned Atomic-Physics Observatory, which will contain a generator and vacuum-tube capable of reaching potentials in excess of 5,000,000 volts with precision control, was begun in May 1937. This equipment will greatly extend the possible scope of the Department's researches on the nature of magnetism and the basic structure of matter.

Prospects are good for an early resumption of the important magnetic survey of the oceans, previously conducted by the *Carnegie* of the Carnegie Institution of Washington until her destruction in 1929, through the proposed operations of the nonmagnetic vessel *Research* under construction by the British Admiralty. The Department continued to cooperate with the Admiralty on the designs of this vessel and her instrumental equipment.

C. R. Duvall and C. C. Ennis, after long and fruitful service, were retired during the report-year. Duvall, expert computer since October 11, 1913, retired January 31, 1937. He took a large part in the reduction of secular-variation data. Ennis, computer and draftsman since December 1, 1915, retired June 30, 1937. Besides invaluable contributions in drafting, computing, and editing, he completed many researches; among these were an examination of the magnetic results of the United States Exploring Expedition under Lieutenant Charles Wilkes during 1838–1842 and studies of correlation between auroral and magnetic activity. His contributions bearing on oceanography and development of methods simplifying computational procedure are outstanding.

The custom at institutions of learning and research of honoring their founders and leaders by setting up in appropriate places some fitting memorial was inaugurated at the Department through the generous gift of a painting of its first Director by Mrs. Louis A. Bauer and her daughter, Mrs. Robert W. Weeks. The painting was unveiled April 3, 1937, in the library of the Department in the presence of President John C. Merriam, Mrs. Bauer, Mrs. Weeks, the members of the Department's staff, and a few invited guests. In accepting the gift President Merriam paid tribute to Dr. Bauer's initiative and far-reaching vision, and the fine structure of the Department's researches already built and building on the foundations so well laid.

## INVESTIGATIONAL AND EXPERIMENTAL WORK

### TERRESTRIAL MAGNETISM

Dr. J. Bartels and Professor S. Chapman, research associates of the Institution, have again this year materially aided the investigations at the Department by constructive suggestion and by their own individual researches at London and at Berlin. Those of the regular personnel taking part in the work reported under terrestrial magnetism include Berkner,



Davies, Duvall, Ennis, Fleming, Forbush, Johnson, Johnston, Ledig, McNish, and Torreson. Professor L. Slaucitajs, of the University of Riga, guest investigator through August 1936, took part in some of the work reported.

#### PERMANENT FIELD

*Origin of the permanent magnetic field and temperatures of the Earth's interior*—Failure to account for the origin of the Earth's permanent magnetic field by any hypothesis consistent with the high temperatures which are usually assigned to the interior calls into question the validity of the assumptions by which these temperatures are derived. During the past year consideration was given to hypotheses that the interior of the Earth might be considerably cooler than is commonly thought. A hundredfold increase in the electrical conductivity of the Earth's substance at a depth of about 200 or 250 km, determined from the terrestrial-magnetic variations, suggests that the thermal conductivity may—although it does not necessarily do so—undergo a similar increase. If such a condition obtains, the mode of cooling of the Earth has been considerably different from what is usually pictured. Solidification would have proceeded from the center outward, but the surface-rocks could never have congealed until the thermal gradient at great depths was  $1/k$  of the thermal gradient in the surface-rocks,  $k$  being the ratio of the conductivity at the surface to that at great depths. Cooling at great depths would have proceeded by conduction to this stage, passage of heat through the more poorly conducting surface-layers being by convection. In this way the blanketing effect of the radioactive surface-layers would be nullified, and the determination of the age of the Earth from radioactivity would apply only to the period after which solidification had become complete. This hypothesis requires a somewhat greater age for the Earth than is given by the radioactivity data, but it is not controverted by them.

The new temperatures deduced from this hypothesis are not low enough for ferromagnetism to exist unless the Curie-point temperature rises with pressure. The experiments of Adams and Green have shown that no large variation with pressure (up to about 4000 atmospheres) occurs, but the technique available at the time did not permit sufficient refinement to rule out a change of Curie-point temperature with pressure sufficient to permit ferromagnetism at the new temperatures for the interior, which may be as low as  $3000^{\circ}\text{C}$ .

*Secular change of the Earth's magnetic field*—Secular change of the Earth's magnetic field was studied further by comparing the data used by Adolf Schmidt and by Furner and Dyson for their analyses of the permanent field for the epochs 1885 and 1922. Charts were constructed showing the distribution of the vectors for the horizontal components of change and isopors for the vertical component. Outstanding on the charts was a region of decreasing northern magnetic potential off the Guinea Coast, where the change in the 37-year interval covered by the charts amounts to 6000 gammas—one-tenth of the value of the permanent field at the poles. That such changes may be due to changes in magnetic state of material slightly below the Earth's surface does not seem likely because large quantities of highly

magnetized matter would be required. It seems quite likely that secular change involves a change in the regions where the permanent field of the Earth originates. Attempts to express the secular change represented by the charts by a spherical harmonic series indicated absence of any relation between the relative values of the changes in the various harmonics and the intensity of those harmonics in the expression for the permanent field. Except for a large value for the first zonal harmonic about the axis of rotation, the series admitted of no simple expression—a fact which has been noted previously by Bartels from analysis of secular-change data from permanent observatories.

*Secular variation in the Pacific*—The final discussion of more than 2200 declination-values obtained by the *Galilee* and the *Carnegie* in the Pacific was completed by Duvall and Ennis. The adjustments, of ten unknowns each, were made in 33 slightly overlapping areas called squares with sides, as a rule, somewhat over  $20^\circ$  in latitude and in longitude. Observations on land were not used because it was thought that the anomalies thus introduced might detract from the accuracy of the results. It turned out that the declination was determined with as great accuracy as could be desired in most of the squares. Although the accuracy to be expected in the annual change has limitations due to the method used, it is nevertheless quite remarkable that in 7 of the 33 squares the probable error of the annual change at the reference-point is  $\pm 0.1$ , and in 9 it is  $\pm 0.2$ . In certain regions of the southern Pacific below latitude  $40^\circ$ , where the observations are few and the range in time-distribution is small, the results are not so satisfactory. It may be that magnetic anomalies, especially to the south-eastward of New Zealand, produce some of the discrepancies noted, although this is to be doubted.

*Isomagnetic charts*—In connection with the above, Ennis prepared large-scale isogonic charts of the North Pacific and of the South Pacific, and an isoporic chart of declination, all for the epoch 1920.0. Ennis and Hendrix completed a new world-chart of total intensity based on the British Admiralty's charts for 1922.

*Electromagnetic measurement of rock-magnetization*—The possibility that the magnetization of rocks may yield interesting information regarding the history of the Earth's magnetic field in past geologic ages and may furnish a basis for rapidly dating various rock-samples has led to experiments on electromagnetic measurement of rock-samples. Particular interest is attached to the magnetic properties of ocean-bottom samples obtained with the apparatus designed by Piggot of the Geophysical Laboratory of the Institution. In the processes of cooling and sedimentation, substances are known to assume magnetization in the direction of the prevailing magnetic field at the time and place of their formation. If this magnetization—as might be expected—is retained through subsequent time, the rocks furnish a record of the Earth's magnetic field extending through past ages, and similarities in magnetic condition of various rocks may be indicative of similar times of formation.

In order that the original magnetic state of the specimens may remain unaltered by the tests, it is important that the specimens should not be

subjected to strong magnetic fields when their magnetization is measured. This provision limits the technique which may be applied in measuring them and prohibits the use of ordinary magnetic measurements. To meet these requirements, attempts have been made by McNish and Johnson to measure the magnetization of specimens by rotating them in a coil which is connected to a tuned amplifier. In this way the specimen is subjected to no magnetic field; plans of the apparatus call for neutralization of the Earth's field during the measurements. So far, the method has not been developed sufficiently to permit quantitative statements, but preliminary experiments promise success for the undertaking.

#### SOLAR RELATIONS

*Bright chromospheric eruptions and magnetic and ionospheric disturbances*—Intensive study during the past year afforded an understanding of how bright eruptions in the solar chromosphere produce marked effects on high-frequency radio transmission and cause a special type of variation in the Earth's magnetic field. The radio effects are manifested by sudden fade-outs of high-frequency reflections from the ionosphere over the daylight portion of the Earth, lasting from a few minutes to an hour or more. The magnetic changes—of a type not recognized prior to this investigation—consist of sudden increases in the normal diurnal-variation departure at stations in the daylight hemisphere coincident in time with the period when radio reflections are not received. All these effects begin simultaneously with the arrival at the Earth of light from bright chromospheric eruptions and cease when the chromospheric eruptions have subsided. Concomitant changes in the natural electrical currents flowing in the Earth's crust at the times of the other terrestrial effects are induced by the magnetic changes. Attention was first called to the terrestrial effects by J. H. Dellinger, of the National Bureau of Standards, and by M. Jouaust, of the Laboratoire Central d'Électricité, Paris, in 1935. Association of them with the bright chromospheric eruptions was accomplished by the Mount Wilson Observatory. All aspects of the phenomena—solar eruption, radio fade-out, and magnetic and earth-current changes—were independently discovered by the staff at the Huancayo Magnetic Observatory during the notable eruption on April 8, 1936.

These effects are attributed to the action of ultra-violet light originating in the solar eruption. Dense ionization is suddenly produced at the base of or below the *E*-region of the ionosphere, where the collisional frequency of the ions and molecules is high. High-frequency radio waves entering this layer are absorbed. Higher layers of the ionosphere are not appreciably affected.

Since the magnetic changes caused by the solar eruptions consist of an augmentation of the normal diurnal-variation departure, even when the diurnal variation is not normal, it is inferred that the diurnal variations of terrestrial magnetism arise through effects occurring in the lower part of the ionosphere, as the radio effects indicate that to be the region affected. This lower region is most favorable for the operation of the dynamo-theory proposed by Balfour Stewart. In accordance with this theory, improved



electrical conductivity resulting from increased ionization permits stronger electric currents to flow, impelled by electromotive forces which are continually present. On the other hand, the diamagnetic and drift-current theories, proposed as alternatives to the dynamo-theory, depend upon processes for which the upper parts of the ionosphere are most favorable. Since these parts are not appreciably affected by the light from the solar eruptions, the observed magnetic changes support the older dynamo-theory against the two more recent ones.

It has been suggested that magnetic storms are due to flares of ultra-violet light from the Sun, identical or similar in character to that originating in the solar eruptions. Since none of the eruptions which have been observed marked the beginning of magnetic storms or were the strongest ones investigated followed by magnetic storms, the ultra-violet theory of storms is not supported by this evidence. Furthermore, the magnetic changes accompanying the solar eruptions are very distinct from those occurring during magnetic storms, which indicates that ultra-violet light is not a likely agent for producing magnetic storms.

Because of the sudden and rapid increase in ion-density, evidenced by the magnitude of the magnetic effects, in a region where the rate of recombination is necessarily great, the ionizing ultra-violet light coming from the Sun at the time of one of these eruptions must be several times as great as the normal radiation of the same type. Since this radiation appears to proceed from a restricted region—possibly only about 0.01 of 1 per cent of the Sun's disk—the intensity of the source must be enormous. That the normal radiation from the Sun in the extreme ultra-violet differs considerably from that of a black body between  $6000^{\circ}$  and  $7000^{\circ}$  is strongly indicated.

#### LUNAR RELATIONS

*Lunar variations*—Preliminary calculations had already indicated that horizontal magnetic intensity,  $H$ , at Huancayo Observatory shows, in southern summer (November to February), the most pronounced lunar influence found in any geophysical phenomenon (apart, of course, from oceanic tides). The whole available series 1922–1934 was therefore subjected to harmonic analyses for every single day, and rearranged according to lunar transit, sunspot-number  $R$ , and international magnetic character-figure  $C$ .

The order of magnitude of the lunar effect ( $L$ ) may be described most simply, without recourse to harmonic analysis, in the following example: Consider the days from months November to February, with zero sunspot-number and magnetic character-figure not over 1.1. This homogeneous material, totaling 317 days, is divided into six transit-groups, designated 2, 4, 6, 8, 10, and 12, according to the transit of the Moon, with no distinction of upper or lower transit. The group designated 2 contains all days with transit-times falling between 1.5 and 3.5 lunar hours before local noon, group 4 those between 3.5 and 5.5, etc. Group 12 contains the days with full and new Moon, group 6 those with first and last quarter; by analogy, group 2 could be called the group of the fifth or eleventh twelfth in the month, group 4 that of the fourth or tenth twelfth, etc. For each day, the 24-hourly means of  $H$  are written in a row, and the average row, that is,



the average solar plus lunar diurnal variation ( $S + L$ ), is formed for each group. In the average row for the six group-means,  $L$  is automatically eliminated; this pure solar diurnal variation  $S$  is a curve with little change during the night hours, and a single wave in the daylight hours. The characteristic feature of this curve is its maximum, which is attained at 10<sup>h</sup>8 mean local time, and is 87 gammas (one gamma is 0.00001 CGS unit) higher than the value for the preceding midnight. The lunar diurnal variation  $L$ , superposed on this average solar variation  $S$ , is most clearly expressed by the change of this forenoon maximum in the six group-averages, as compared with the maximum for  $S$ . These changes affect the phase (maximum attained at 10<sup>h</sup>3 in group 12, and at 11<sup>h</sup>3 in group 8), but above all the height of the forenoon maximum above the level of the preceding night, namely, only 65 gammas for group 2 and 104 gammas for group 10. These changes are large enough, even compared with the ordinary variability of the solar diurnal variation  $S$ , to make the lunar influence  $L$  visible even in the records for single days.

This exceptional magnitude of  $L$  at Huancayo in southern summer allows accurate tests of its changes with daily sunspot-number  $R$  and character-figure  $C$ . Two classes of days were formed, with  $R$  under 30 and with  $R = 30$  or more, the average  $R$  in the two classes being about 8 and 72. The amplitudes of the first, second, and third harmonic terms (24-hourly, 12-hourly, and 8-hourly wave) of the solar diurnal variation increase from the first to the second class by 50, 29, and 24 per cent, respectively. For the lunar diurnal variation, these increases from small to high sunspot-numbers are decidedly smaller, namely, 9, 12, and 8 per cent.

This significant difference in the reaction of  $S$  and  $L$  to changes in solar activity furnishes a criterion for theories of the ionosphere. Chapman has shown how, on the dynamo-theory of diurnal magnetic variations, changes in the intensity  $I$  of the ionizing solar radiation are reflected in changes of the amplitudes  $A$  of the magnetic variations. If the latter changes were due only to changes in the number of ions per cubic centimeter (which is proportional to the square root of  $I$ ),  $A$  should also be proportional to the square root of  $I$ ; if, however,  $I$  also produced the mechanical atmospheric circulation responsible for  $A$ , then  $A$  should be proportional to the third power of the square root of  $I$ . Now the first alternative seems to meet the case of  $L$ , while the second one might fit  $S$ . With a change of  $L$  by about 10 per cent we should then expect a change of  $S$  by about 30 per cent. This is quite compatible with the values found above. The layers in which the electric current-systems for  $L$  and  $S$  are circulating could therefore be considered as both changing their ion-content by about 10 per cent with an increase of sunspot-numbers from 8 to 72, and nothing so far prohibits the conception that the two layers for  $S$  and  $L$  may be one layer only, possibly near the  $E$ -layer. In comparison with wireless results, which have been interpreted as indicating an increase of some 45 per cent in ionization of the  $E$ -layer from minimum to maximum of sunspots, the increase in  $L$  appears definitely smaller.

The change of  $L$  at Huancayo with magnetic activity is surprisingly small in southern summer. Comparing quiet days with  $C$  up to 1.1 and disturbed

days with  $C$  between 1.2 and 2.0 (the number of the latter being about one-sixth that of the former), the percentage increases of  $L$  in the amplitudes of the first three harmonics are 17, 4, and 9 only. In  $S$ , the characteristic change from quiet to disturbed conditions is the addition of the well-known 24-hourly "disturbed-day" wave with maximum about 6<sup>h</sup> local time, and amplitude about 17 per cent of the quiet-day amplitude; in the second and third harmonic terms, the changes are only a few per cent.

Other inferences from these diurnal magnetic variations have been discussed by Bartels in full in a paper communicated to the Deutsche Geophysikalische Gesellschaft.

Chapman has made extensive reductions in bihourly magnetic data for Helwan (all three elements) and Batavia (declination) to determine lunar diurnal changes. Similar reductions to determine lunar atmospheric tides at many stations, including five in the United States, five in Japan, three in Spain and Portugal, and others, have been made. The stations in the United States included Mount Wilson and four stations of the United States Weather Bureau. Chapman has prepared a description of the theory and methods used for these large-scale compilations.

#### MAGNETIC DISTURBANCES

*Cosmic radiation and magnetic variations*—Utilizing cosmic-ray records made available by the Institution's Committee on Coordination of Cosmic-Ray Investigations from Huancayo (Peru), Cheltenham (United States), Teoloyucan (Mexico), Christchurch (New Zealand), and Cape Town (Union of South Africa), Forbush investigated possible relationships with magnetic and other phenomena. Comparison of the daily means of cosmic-ray intensity for Huancayo, Cheltenham, and Cape Town showed similarity between the three and suggested the possibility of world-wide changes in cosmic-ray intensity. A study of such changes occurring at Huancayo and Cheltenham simultaneously with changes in magnetic horizontal intensity during the magnetic storm beginning April 24, 1937, showed definitely for the first time that a magnetic storm can produce world-wide changes in cosmic-ray intensity. The horizontal magnetic intensity decreased about 5 per cent during the storm, while the cosmic-ray intensity decreased nearly 4 per cent at all three stations. The magnetic-storm effect on cosmic-ray intensity may provide important evidence for determining the height of the current-system of magnetic storms. An investigation to determine whether minor world-wide disturbances in the Earth's field are accompanied by such changes is under way.

Statistical analyses were made of the cosmic-ray data obtained at Cheltenham from April 1935 to October 1936. The results demonstrated the existence of a statistically real solar diurnal variation in recorded cosmic-ray intensity. The statistics obtained permit tests of possible causes of solar diurnal variation and tests for the existence of a sidereal variation as reported by some investigators. The analyses indicated two other results of vital importance, namely: (1) the barometric coefficients derived from different samples of data are statistically in agreement, and (2) the observed solar diurnal variation is independent of the diurnal variation in atmos-

pheric temperature as measured near the ground. Preliminary similar analysis of the data obtained from Huancayo indicates a solar diurnal variation roughly in agreement with that obtained at Cheltenham.

Preliminary investigations based on the Cheltenham data as regards sidereal diurnal variation and lunar diurnal variation in cosmic-ray intensity do not indicate the existence of statistically real effects of this type. These investigations are being continued in conjunction with the analysis of solar diurnal variation for the Huancayo data.

*Cooperative studies of magnetic-disturbance phenomena*—During the year Chapman supervised several special investigations by postgraduate students at the Imperial College of Science and Technology in London. Thus, E. H. Vestine studied geomagnetic disturbance-phenomena in the polar regions, using data for many stations from the Second International Polar Year supplied through the courtesy of Dr. la Cour. The Rolf geomagnetic giant pulsations and their primary and induced current-systems were studied by M. A. El Wakil. In conjunction with A. T. Price, B. N. Lahiri investigated distribution of the electrical conductivity within the Earth as determined from the daily magnetic variations and magnetic-storm data.

*Disturbance-fields*—McNish continued investigation of the magnetic disturbance-field associated with magnetic bays and possible current-systems which might give rise to them. He and Slaucitajs discussed the field of magnetic storms as deduced from the mean difference of magnetic intensity on quiet and disturbed days. The current-system derived from the spherical harmonic analysis exhibits three regions of maximal intensity near the equator and near the auroral zones.

#### MAGNETIC ACTIVITY

*Method of adequately describing magnetic disturbances and perturbations*—As Chairman of a joint committee of the Association of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics and the Commission of Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Organization, Fleming studied methods and codes for adequate description of magnetic disturbances and perturbations. The results were incorporated in a report presented at the Edinburgh Assembly of the Association in September 1936. The prompt dissemination of such information is increasingly important because of the rapid advance in study of effects of changes in the Earth's magnetism on wired and wireless communication and of their close relation to cosmic phenomena including solar activity.

*American magnetic character-figure  $C_A$  for half-days*—The close relationship of radio transmission-conditions with terrestrial-magnetic storms indicates a need for an accurate and immediately available measure of magnetic disturbance for scientific studies and for prediction of those conditions. The international magnetic character-figure  $C$ , inaugurated in 1906 and published quarterly, fails to fulfill this need because the published data are not supplied soon enough, the time-interval—an individual day—is not short enough for adequate comparison, and the scale of 0, 1, and 2 does not



allow sufficient gradation for classification. To supply these needs the Department, with the cooperation of the United States Coast and Geodetic Survey, the communication-services of the United States Army and the United States Navy, and several radio amateurs, undertook, beginning March 13, 1937, to supply weekly bulletins on the state of the Earth's magnetic field for each Greenwich half-day. These bulletins are based upon the estimates of magnetic character communicated by radio or telegraph from the two observatories of the Department and the five observatories of the United States Coast and Geodetic Survey. The average character-numbers, after compilation at the Department, are disseminated to interested parties through the weekly Science Service Research Aid Announcement. Quarterly summaries are published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*. This measure has been welcomed by both commercial and scientific organizations, and advance estimates of radio transmission-conditions based upon it have already borne out the expectations of its sponsors.

#### ARCHIVES OF MAGNETIC RECORDS

*Polar-Year magnetic records*—The Department acts as a central bureau for disseminating Polar-Year magnetic records on this side of the Atlantic. There have now been received from the Central Bureau of the Polar Year Commission at Copenhagen, Denmark, 667 miniature film-records from 33 observatories. Each film gives one month of daily magnetic records from one observatory. The availability of these records offers the Department and other organizations on this side of the Atlantic a unique advantage in the study of terrestrial-magnetic phenomena.

#### INSTRUMENTAL DEVELOPMENTS

*Electromagnetic methods*—The design and construction of a new type of primary standard of high precision for measuring the magnetic vector of the Earth's magnetic field, begun last year, was continued by Johnson. The instrument consists of a carefully constructed Helmholtz coil and a rotating-coil alternating-current detector of the type previously developed and described. The construction of the coil-form was begun early in 1937 and is now about half completed. The instrument is designed to measure the horizontal and vertical components of the magnetic vector and the declination, thus completely specifying the magnetic field at the point of measurement for the first time with a single instrument. A null method of measurement will be used, so that the measurement does not depend upon the detector, and the magnetic field is computed from the dimensions of the Helmholtz coil and the current in its windings.

To assure that this standard shall have an absolute accuracy sufficient to determine the value of the Earth's magnetic field to one part in one hundred thousand, or 0.5 gamma in the vertical component, it is necessary to obtain the coil-constant with much greater accuracy, for example, a few parts in a million. The limit of absolute accuracy will then be set for the time being by the absolute value of the ampere, which is still uncertain, but when the value of the ampere is determined with greater accuracy in



the future the values used with this coil can be corrected to the more precise value.

To obtain an accuracy of a few parts in a million in the coil-constant, or about an order of magnitude better than previous coils, and still restrict the coil-dimensions to practical values, it was necessary to design and construct the coil-form with the greatest of precision. Pyrex was chosen for the coil because of its relatively superior electrical and mechanical properties. Electrically it is ideal since its surface- and volume-resistivity are high and the effect of high humidity can never cause any serious error. Mechanically it has a low temperature-coefficient, it can be ground and lapped by a well-developed technique, and with proper aging treatment it is relatively stable in its dimensions, with respect both to temperature-hysteresis of dimensions and to permanent set with age. These properties are especially favorable as compared with those of marble, the material used in the previous important primary standards.

The coil-winding and current-leads were designed to reduce the errors arising from the uncertainty of end-effects. Each coil is double, which allows the measurement of insulation-resistance, and, because of the geometrical arrangement, the end-effect of the uncompensated part of the current-leads is zero, as is the effect of the axial component of current in the two current-sheets. The voltage induced in the rotating coil may thus be computed from the expansion of the magnetic field about the center of the system in spherical harmonics. This has the hitherto unrealized advantage that a correction can be applied for the finite dimensions of the detector, which, although small, is exact and allows an increased precision in computing the field.

For the desired accuracy it is necessary that all the dimensions of the coil be uniform to better than a micron. Methods were devised to fulfill this requirement, including the construction of an especially sensitive electrical micrometer, which reads directly in microns, to measure coil-dimensions during grinding. The actual grinding of the coil-form has proceeded to the point where it is now ready for the final lapping of the grooves in which the wire will lie. Up to this point all the requirements of accuracy have been more than sufficiently met.

After casting, from the same pyrex as the second 200-inch mirror, the coil was thoroughly annealed and aged for over two years, and is now being passed through a number of heating and cooling cycles (from  $+100^{\circ}\text{C}$  to  $-70^{\circ}\text{C}$ ) to remove hysteresis. After the time-aging it was rough-ground in a temporary lathe, using a steel disk 18 inches in diameter, rotating at several hundred revolutions per minute, with No. 40 to 80 carborundum in water as an abrasive. This shaped the outer part of the cylinder and the ends to  $\pm 0.005$  inch. The inside was then ground and polished to within  $\pm 0.0002$  inch. After this the coil was centered in a lathe and the ends and outside cut to  $\pm 0.0001$  inch with a diamond tool, and finally the double spiral thread was cut to guide the brass lap for finishing the threads, the pitch being chosen to obtain as nearly as possible the exact Helmholtz relation. These last operations were examined during processing with a microscope, to insure uniformity of pitch and depth of thread.

For mounting the coil a rigid clamp may not be used because of the large compressive forces caused by changes in temperature. The coil-form rests on a duraluminum plate, and is enclosed in a duraluminum cylinder which protects it mechanically and at the same time acts as an electrical shield. The coil may be oriented about a vertical and a horizontal axis, the circle about the vertical axis allowing the determination of declination.

A most important problem is the determination of the absolute susceptibility of the materials used, because of its effect upon the field inside the coil. The astatic magnetometer mentioned in the last annual report was perfected by Johnson and Steiner, and a method of determining the absolute susceptibility of the actual parts was developed to values of susceptibility as low as  $10^{-8}$  electromagnetic CGS unit. Measurements on the glass of the coil-form showed it to be diamagnetic with a susceptibility of approximately  $-0.5 \times 10^{-8}$  CGS unit. The copper used in the CIW sine-galvanometer was also measured and found to be  $-0.68 \times 10^{-8}$  CGS unit, while the marble of the coil-form was paramagnetic with a susceptibility of  $+0.5 \times 10^{-6}$  CGS unit.

In addition to the work on the primary standard, the design of the companion observatory-and-field instrument of the same type was considerably advanced. The general problems involved are similar except that ruggedness, as well as permanence, is a prime requisite, while the coil-constant may be determined by comparison with the primary standard rather than by measurement of its dimensions.

*Automatic current-control*—During the early part of the report-year an automatic current-control was developed by Johnson; this will find important applications to instrument recording. It allows the registration of the magnetic elements by means of pen-and-ink recorders and was successfully applied to a leak-free method of recording potential-gradient.

*CIW induction-variometer*—The induction-variometer for measuring time-variations in the vertical intensity of the Earth's magnetic field, developed during the preceding report-year, has been kept in operation at the Cheltenham Magnetic Observatory throughout the past report-year to obtain a rigorous test on its performance. This test has demonstrated that the instrument is free of the faults inherent in the older types of instruments and fulfills the need of a satisfactory instrument which has been felt for the past half-century.

#### PUBLICATIONS

A large number of communications on terrestrial-magnetic investigations above noted, as indicated in the Bibliography given elsewhere in this Year Book, were prepared and presented at the Assembly of the International Union of Geodesy and Geophysics at Edinburgh, Scotland, in September 1936. At that Assembly, in his address as President of the Association of Terrestrial Magnetism and Electricity, Fleming reviewed the progress in the past three years of research in terrestrial magnetism and electricity. McNish addressed the National Academy of Sciences April 27, 1937, on "Terrestrial effects associated with bright chromospheric eruptions," as also (with Ludy) the American Section of the International Scientific Radio

Union April 30, 1937, on "The American character-figure  $C_A$  as a measure of the magnetic activity of the Earth."

### TERRESTRIAL ELECTRICITY

The electrical phenomena and properties of the Earth and its atmosphere, designated "terrestrial electricity," are of two such distinct classes that subdivision into atmospheric electricity and geo-electricity is natural and convenient. Atmospheric electricity embraces electrical phenomena and properties of the atmosphere. Geo-electricity includes that branch of terrestrial electricity which pertains to natural electrical phenomena occurring in the Earth and to those electrical properties of earth-materials which play a part in the genesis or development of some of the aspects of electrical phenomena. Those members of the staff engaged in the investigations of the Section of Experimental Work in Terrestrial Electricity were: in atmospheric electricity, Forbush, Gish, Korff (guest investigator from October 20, 1936, to April 16, 1937), Mauchly (temporary assistant, June 20 to August 28, 1936), Sherman, Torreson, and Wait; in geo-electricity, Gish, Keck (guest physicist, July 1 to August 29, 1936), and Rooney.

### ATMOSPHERIC ELECTRICITY

*Fair-weather electric field*—Electrical phenomena such as those which are a conspicuous characteristic of thunderstorms have not yet been intensively investigated at the Department. The investigations have been directed rather to a study of the electrical phenomena which are observed during fair weather. The electric field-strength, or electric intensity, in the atmosphere during fair weather, while averaging about 130 volts per meter near the Earth's surface, varies considerably from place to place and from time to time. Some of these changes are regular, that is, they run in cycles of a day and of a year and possibly also of longer periods. One alluring aspect of those cycles is that they appear to be of about the same character and to follow a time-schedule which is nearly the same everywhere on the Earth except at places where such conditions as, for example, the presence of dust or forms of atmospheric pollution affect the electrical properties of the atmosphere to such an extent that a local time-schedule is imposed upon the world-wide schedule and thus conceals the universal aspect of the cycle. The evidence for a daily cycle—first revealed in data obtained over the oceans on cruises of the *Carnegie*—is now so strong that few, if any, question its existence. The evidence that cycles of longer period are essentially universal in character is not conclusive; the data being accumulated by the Institution's observatories at Watheroo and at Huancayo and by two co-operating observatories at Apia and at Tucson will be soon sufficient to determine whether the longer cycles have a universal aspect. Some general preparatory work was done during the year by Wait, Torreson, Sherman, and Mauchly to mobilize and to marshal a great mass of data for adequate evidence on this as well as on other problems which parallel it. Wait and Mauchly, from a limited amount of material, found some evidence that, if the average of the electric field for a year is large or small at one place, it tends to be large or small, respectively, at other places, even though these



be far apart. Such a conclusion, if established, is of interest in itself, but the final result, whether positive or negative, is also important for the bearing it may have on any solution offered for the outstanding fundamental problem of atmospheric electricity, namely, how does the Earth acquire and maintain the negative charge which is detected on its surface wherever fair weather prevails.

The air, although generally regarded as a good insulator, conducts electricity, because of the ions ever present, to such an extent that for the average observed field-strength and conductivity the total current flowing from air to Earth for all fair-weather areas of the Earth is estimated to be 1500 amperes or more. This current represents the rate at which the Earth is losing negative charge over fair-weather areas owing to electrical conduction. However, there must be some mechanism which on the average offsets this loss, else the charge of the Earth and the electric field would both vanish within an hour or so. The source of this charging current—the most fundamental phenomenon of atmospheric electricity—may perhaps be found in storm-areas where the electric field is intense and exceedingly variable. Conditions in general are so unfavorable to making the required quantitative measurements over a sufficiently representative area of the Earth that scarcely a beginning has yet been made in the investigation of this possibility. However, something may be learned about the characteristics of the charging current by a study of the discharging current which flows from air to Earth in fair-weather areas and which is measured continuously by either direct or indirect means. At Watheroo, Huancayo, and Tucson this is done indirectly by registering continuously the field-strength and the electrical conductivity of the air. The product of the field-strength by the total electrical conductivity is then the air-earth current. This (the discharging current) when suitably averaged or integrated for a sufficiently representative area of the Earth must on the average over longer periods be equal to the average of the unknown charging current. This holds for averages of data from a wider distribution of observatories than has thus far been realized. However, when factors that modify the discharging current are taken into account, data of less extensive geographical distribution are required.

*Ionization of the lower atmosphere*—Of these factors, apparently the more important are those which affect the electrical conductivity of the air by limiting the number or the mobility and the distribution of those small ions which are the effective electric carriers in the atmosphere. The number of ions, or the density of the ion-population, depends primarily upon the rate at which they are destroyed or removed. Both of these opposing tendencies and the relation between them and the population-density of ions of several types were investigated by Wait and Torreson during the report-year. This was done by continuous registration of the rate at which ions are formed in a thin-walled closed chamber and of the population-density of small, intermediate, and large ions. From the abundance of small ions and large ions, and the rate at which the small ions are produced, the value of the combination-coefficient between small ions and large ions was computed. The value of this coefficient varies as the size of the large ion. The coefficient of combination was found to be highly correlated with the amount of



water-vapor in the air, a result which suggested that as the water-vapor increased the large ion increased in size. This is contrary to suggestions of other workers that the size of the large ion is a function of the relative humidity.

Another approach to this problem was obtained through a formula, developed by H. L. Wright, relating the size of the large ion with the number of condensation-nuclei, charged and uncharged. Data taken in Washington in 1931 with the nuclei-counter and the large-ion counter, using Wright's formula, again show no correlation between size of the large ion and relative humidity, but do show a high correlation between size and absolute amount of water-vapor in the air. This result is in agreement with that obtained from the study of the combination-coefficient between small and large ions.

Continuous records with two similar thin-walled ionization-chambers make possible study of the relative amounts of positively and negatively charged radioactive material in the air, the precision with which the rate of ionization is measured, the amount of ionization ascribable to alpha particles, beta particles, and gamma rays from radioactive material in the air and soil, and other valuable information. Thus far but little of this information has been secured. However, comparison has been made of the rate of ionization inside the two thin-walled chambers, with different signs of potential on the outer electrodes. No appreciable difference in ionization could be noted whether the outside electrode was positively charged or was without charge. On the other hand, approximately four times as much ionization occurred inside the chamber having a negative charge on the outside electrode as in the chamber with zero charge. These experiments indicate that a large part of the radioactive products in the lower atmosphere is positively charged, thus supporting other results.

*Ion-forming agencies and rate of formation*—Ions are formed in the thin-walled chamber by the radiations from radioactive matter in the Earth and in the atmosphere and by the cosmic radiation. These are the principal ion-forming agencies near the Earth. The radioactive matter is, however, not present everywhere in the atmosphere. Since it escapes to the air from the soil, it is found in greatest abundance near the surface over land, the amount over mid-ocean being not more than a few per cent of the average found over land. The radioactive matter in the air diminishes rapidly with distance from the Earth's surface, until at altitudes greater than one kilometer it doubtless contributes very little to the ionization of the air. In the region of the atmosphere extending some tens of kilometers upward from this level, and from sea-level upward over much of the ocean-areas, and probably also over the snow-covered polar caps, the cosmic radiation is apparently the preponderant ion-forming agency. Aspects of this important factor in atmospheric electricity were investigated by Forbush and Korff; the former evaluated cosmic-ray registrations obtained at Cheltenham and at Huancayo, and by means of a statistical analysis of the data studied the barometer-effect, temperature-effects, and the diurnal variation. Korff devised and constructed a light-weight short-wave radio transmitter that was piloted by a Geiger-Müller counter and when carried aloft by a sounding-balloon sent out a signal whenever a cosmic-ray corpuscle passed through the

counter; at intervals it also sent signals which gave a measure of the altitude of the balloon. In cooperation with the National Bureau of Standards these were picked up and recorded on apparatus already developed by and located at the Bureau.

In addition to the rate at which ions are formed in a given portion of the atmosphere, the rate at which they are introduced into or removed from that space should also be considered. This aspect is generally neglected in the formulation of the equilibrium-relations usually used to obtain from experimental data the coefficients that enter the relations, or for calculating the magnitude of an unknown factor. Gish made a theoretical investigation to determine more precisely the conditions under which that practice is admissible and the possible magnitude and character of errors that may arise when the oversimplified relations are used under the conditions that actually exist in the atmosphere. Some of the simpler conclusions reached may be stated briefly as follows: Since it is necessary, because of practical considerations, to use the simplified relations for evaluating the coefficients from measurements of the several factors, the measurements are best made at the center of a large closed room in which the air is gently mixed and where the rate of ionization is enhanced by radioactive matter, preferably without gamma radiation, distributed on the walls. Conditions can probably be made more favorable by providing for the introduction at a constant rate of substances which provide the nuclei to which small ions attach to form large sluggish ions. The effect of the Earth's electric field near the surface (the electrode-effect) is of such character and magnitude that one cannot expect the measurements made in the open air to satisfy the simple relations. The errors from this source are variable, but errors of one sign preponderate, so that these are not eliminated when the means of a long series of measurements are used. Consideration of the more general relations indicates that the coefficient for the rate of combination between small ions and uncharged nuclei, or that for small ions and large ions, when calculated from the measurements with the aid of the simple relations, may depend upon humidity owing to errors that enter when some of the conditions of the experiment do not conform with those assumed in the simple relations. The circumstances existing in the atmosphere at a given time may be so complex that even an approximate test of the more general relations for ionic equilibrium would require an impracticably elaborate observational program. However, if the coefficients proper, and their dependence upon such factors as humidity, temperature, pressure, etc., are known, the averages of measurements obtained over a period of time from a less elaborate program should serve to test the equilibrium-relations or to determine the general character of features which cannot be as readily ascertained by other means.

A knowledge of the manner in which the coefficient of combination between small and large ions depends upon pressure is urgently needed for a fuller interpretation of measurements of air-conductivity such as were obtained on the flight of *Explorer II* into the stratosphere on November 11, 1935. In the full report of those results by Gish and Sherman there is one interpretation which pertains to the distribution of nuclei in the atmosphere. When

preparing that report it was thought that the most probable of several possible quantitative interpretations of the difference between the value for air-conductivity registered at a given altitude and that calculated from the intensity of cosmic radiation measured at a corresponding altitude, was that this difference appears because in the first place no allowance could be made in the calculations for resulting diminution of conductivity had nuclei been present in sufficient number. It was known at the outset that for the first 3 or 4 km from the Earth the calculated values would differ appreciably from the corresponding measured values because this factor was not included in the calculations. However, from the ratio of the calculated values to the measured values the number of nuclei per cubic centimeter that is required to account for the disparity may be estimated, provided one knows how the rate of combination of small ions with large ions and with uncharged nuclei varies with temperature and pressure. The dependence upon temperature is probably of minor importance, at least in the stratosphere, where the temperature is nearly the same at all altitudes. However, the dependence upon pressure has never been investigated in the laboratory, so that one has only unverified and disputed theoretical derivations to rely upon for guidance.

Assuming the rate of combination to vary directly as the pressure, and the disparity between observed and calculated values to be wholly due to the presence of nuclei, the number calculated was so great and the distribution was of such a character that it seemed inadmissible to attribute the whole of the disparity to the presence of nuclei. However, there appeared considerable doubt as to the manner in which the coefficient of recombination of positive small ions with negative small ions varies with pressure. It was found that if that coefficient varies not as the first power of pressure (the relation first used in calculating conductivity from cosmic-ray data) but nearly as the cube root of the pressure, then there would be no important disparity to attribute to nuclei in the large altitude-range from 6 to 18 km. Above and below these altitudes the disparity, now reduced, could be more acceptably regarded as due to nuclei.

Another possible interpretation, examined in more detail since that described above was published, relies upon a method of treating the data similar to that just outlined except that, while the recombination-coefficient for small ions was taken to vary directly as the first power of the pressure, the coefficient of combination of small ions with large ions was taken to vary inversely as the pressure. According to the calculations made in this way the number of nuclei required to account for the disparity between the calculated and the observed values of conductivity is not objectionably great and the distribution of the nuclei with altitude for altitudes greater than 3 km is about the same as that calculated for very small spherical particles that are introduced into the high atmosphere at a uniform rate and fall at a rate given by the Stokes-Cunningham law. In this respect, then, there is no physical objection to this sort of interpretation. However, there is another result of these considerations that is more difficult to accept, namely, the extreme effectiveness of nuclei in reducing the conductivity at the higher altitudes. Thus, for example, at 18 km the presence of 85



nuclei in one cubic centimeter would reduce the conductivity 60 per cent, and the effectiveness would increase at higher altitudes. These trial interpretations suggest problems for investigation in the future.

The electrical properties and phenomena of the atmosphere near the Earth are also affected by the circumstance that the electric field during fair weather drives negative ions away from the surface of the Earth faster than they can be replenished, thus diminishing the number at the Earth's surface, whereas positive ions which are brought downward are not diminished in number by this process. As a result the number of positive ions is greater than that of negative ions, so much so that the positive ions play a greater rôle in the transport of electricity than do the negative ions. Another result is that the field-strength is increased near the Earth. The magnitudes of these so-called electrode-effects are interdependent, and the altitude to which they extend depends, furthermore, upon the interplay of those opposing tendencies mentioned earlier in this report, which determine the ion-balance in the atmosphere. Mathematical relations designed to express this dependence have been derived by several investigators for various ideal conditions. Gish succeeded in making these relations more general in some of their aspects and in putting them into forms which may be used in the study of actual measurements.

*Reductions of Polar-Year records*—Sherman organized data obtained at College, Alaska, during the Second International Polar Year, and worked out empirical relations between the field-strength and the ratio of the part of the conductivity contributed by the positive ions to that contributed by the negative ions, for the purpose of ascertaining whether the mathematical relations mentioned above adequately describe the observed effects. In the present stage of this study it appears that the ratio of positive to negative conductivity is related to field-strength in the manner indicated by the mathematical relations. That relation also undergoes systematic variation during the year. These relations appear distinctly even though there are many random departures from them. Since some of the factors involved in the effect were not measured at all times, if at all, this study of the data is expected to constitute a test of the theory of the effect in its more general features only, but a more exhaustive test than has thus far been made. A complete report on the methods and apparatus used for registering atmospheric-electric elements at College, Alaska, during the International Polar Year and on the results was nearly completed by Sherman.

*Instrumental developments*—Gish designed equipment for use on aircraft to measure the electric field-strength. The design is such that if the equipment is placed in certain positions of symmetry, relative to the electric field which may arise from electric charges developed on the craft, the measurements are then unaffected by that charge.

A convenient regulator-unit for use with the "leak"-free and null method of measuring the electric field-strength in the atmosphere was designed by Sherman, who also prepared for publication a note describing it and its use in measurements of field-strength.

Various tests of instrumental equipment were made for the observatories or for cooperating organizations. Ionium-coated collectors for use in measur-



ing air-potential were prepared, standardized, and loaned to the Kansas State College and to the University of Cincinnati.

To secure more complete data regarding the so-called "current-voltage" characteristic of the air-conductivity apparatus used on the flight of *Explorer II* and because results reported by some other investigators for their instruments indicated serious disagreement with the characteristic that would be derived from theoretical relations, Sherman repeatedly determined characteristics of that instrument for various conditions of turbulence in the air-stream. It was found that the point at which saturation-current set in was a fairly sharp knee and that it was very close to the calculated value. Effects of turbulence were noticeable only in observations well out on the saturation limb of the characteristic.

#### GEO-ELECTRICITY

Of the several classes of electrical phenomena which are known to occur in the Earth, two were investigated at the Department during the report-year. One, commonly designated "earth-currents," embraces electric currents of natural origin which circulate in extensive eddies within the Earth, and are intimately related to some of the changing aspects of the Earth's magnetism. The other class has no commonly accepted designation. It comprehends electrical potentials of the Earth in mountainous regions, which frequently have been found in such a relation with reference to the slope of a hill or mountain that some investigators have regarded these observations as evidence that electric currents in the Earth on all sides of a mountain flow from the base toward the summit. Those who entertain such an interpretation refer to these phenomena as "vertical earth-currents." That term may, however, have an unfortunate connotation. It would seem better to wait until more is known about these interesting phenomena before attempting to fix upon a name for them.

*Solar relations of earth-currents*—The earth-current records were examined for correlation between earth-current deflections and the bright solar eruptions accompanying radio fade-outs. Further attention was given also to the variation of the diurnal range in earth-currents during the sunspot-cycle. Ranges greater than any registered at the maximum of the last sunspot-cycle were reached at Huancayo early in 1937, and the records from Tucson show a steady increase in range since 1932.

*Earth-current periods*—The study of the variation in the daily mean values of earth-current potentials to determine the existence and magnitude of components in earth-current flow with periods longer than one day was completed by Rooney and prepared for publication. This investigation indicates that part of the current flowing during disturbances is unidirectional for the day. The magnitude of this "disturbance-component" is only a few per cent of the range of the diurnal variation. Its direction at a given station is consistent with that noted in the diurnal-variation records.

*Lunar diurnal variation in earth-currents*—Determination of the lunar diurnal variation in earth-currents was begun by Rooney. So far, this study has been confined to an examination into the requirements for satisfactory evaluation, the amount of data necessary, and the preferred method of working out this variation. Using the method employed by Chapman for the

magnetic elements, the Tucson records for 1932, near the sunspot-minimum, were rearranged to show the lunar diurnal variation. The data for this single year reveal a definite lunar diurnal variation of markedly double period for both the northward and eastward components. Harmonic analyses show that the amplitude of the second harmonic is about one-fifth of that found in the solar diurnal variation for the same year, while the amplitudes calculated for the first, third, and fourth harmonics are all negligibly small.

Portions of the data for the same year were also investigated for lunar diurnal variation by the method applied by Egedal to the data from the Ebro Observatory. In this method the lunar diurnal variation is obtained from the records for individual solar hours of the day. Using the hours from 12 to 24, the lunar diurnal variation found is in good agreement with that found by the first method from this half-year's record. Comparison of the lunar diurnal variation obtained separately by this method during daylight, 12<sup>h</sup> to 18<sup>h</sup>, with that obtained during night hours, 18<sup>h</sup> to 24<sup>h</sup>, showed no decided difference in either amplitude or phase. In this respect the results are in disagreement with those of Egedal, which showed considerable difference in both phase and amplitude between the lunar diurnal variation worked out for the day and that for the night. A single year's records are scarcely sufficient, however, for a comparison of this sort; Egedal's work as well as that reported here covered only one year's record.

The investigation so far done indicates that the general features of lunar diurnal variation in earth-current are determinable from a comparatively brief series of records, at least when, as at Tucson, long lines are used. To determine how the magnitude and character of the lunar diurnal variation varies with season, with phases of the moon or solar time, or with the sunspot-cycle, will require a much greater volume of records. With reference to the choice of methods it appears that, while Egedal's method is somewhat more convenient, that used by Chapman is preferable for dealing with earth-current data, since it is less likely to be affected by changes in the contact-potentials at the electrodes. This consideration is far more likely to be of importance when using data obtained with short lines, as for example at Huancayo, Watheroo, and Ebro, than it is when data from long lines like those at Tucson are used. A preliminary study of lunar diurnal variation in earth-currents at Huancayo is under way.

*Improvements in earth-current systems*—On the Tucson system new electrodes were installed at Mammoth and Wilcox because of the gradual deterioration of the insulation on the underground sections of the connecting leads. The original electrodes contemplated operation for only a year or two but functioned satisfactorily for five years; hence the new electrodes should permit completing records for a full sunspot-cycle without further changes. Anticipating the approaching sunspot-maximum, the sensitivity of the galvanometer-units at Tucson was reduced to prevent off-scale deflections. Practically no loss of record from off-scale deflections occurred during the year since this change was made. Some loss of record does occur during periods of intense disturbances because of rapid oscillatory motion of the galvanometers at such times and the consequent fading out of the trace on the record. Since the installation of an auxiliary insensitive gal-

vanometer in series with that used for the normal registration of a given component would insure complete records of disturbances, it is planned to make that addition soon.

*Geo-electric phenomena in mountainous regions*—Experiments in the laboratory and field designed to show more about the character and genesis of that class of geo-electric phenomena which has been observed chiefly in mountainous regions were made by Rooney and W. G. Keck, of Michigan State College, under the direction of Gish. Following tests at the laboratory to determine the type of electrodes best suited, measurements in the field were begun late in July on Pass Mountain in the Shenandoah National Park, near Luray, Virginia. Porous pots containing copper in a saturated solution of copper sulphate were used for electrodes. Measurements of potential-differences were made along a line running from west to east across the mountain and spanning a total distance of about 5.5 km. The elevation of the west end was 400 m, from which point the elevation increased fairly uniformly to a little over 900 m at the mountain-top and then decreased to about 450 m at the east end of the line. Measurements of potential were made in steps of about 500 m and checked by reversing the electrodes and using from two to four electrode-positions at each end of the line. Intermediate measurements spaced 50 and 100 m were also used to check many of the results. The results showed an apparent electrical gradient of fairly constant magnitude and direction all along the line from west to east. They do not support the conclusion reached by a number of observers that the electrical potential-gradient in mountainous regions is always directed from the base to the top of a mountain. The direction of flow indicated in these experiments was up the slope on the west side of Pass Mountain and downward on the east side. The results do indicate the possibility that large local circulations of current occur in such mountainous regions.

The hydrogen-ion concentration in samples of soil taken at each electrode-position showed no correlation with the measured potentials. However, the method of taking samples of soil, including as it did only the finer materials at the surface, is not considered to be entirely satisfactory. Tests in the laboratory to determine the magnitude of the potentials due to electrochemical action at the electrodes or the contact-potential between two soils were made later by Keck at Michigan State College, but without giving an adequate explanation of the large potentials recorded.

In a concluding analysis of the observations and experiments that are at hand to date, Gish recommended that investigation in the laboratory be made of the electrokinetic potentials between ground-water and the porous material through which it moves in order to estimate more correctly the magnitude of the potential that may be developed by the movement of water in the soil or other porous earth-materials. From the theory of the effect, one would expect considerable potentials to be developed at places in the Earth where large hydrostatic pressure-differences obtain, provided the electrokinetic potential between the ground-water and the porous structure through which it moves is appreciable. However, it is known that the effect is sensitive to the chemical constitution of the solid and liquid phases, so that esti-



mates based on theory and the available data in the laboratory may be misleading.

### INVESTIGATIONS OF THE IONOSPHERE AND ITS RELATION TO TERRESTRIAL MAGNETISM

A definite advance was made during the past year toward the experimental connection of phenomena of the ionosphere with magnetic effects. The evidence yielded by the automatic recorders at the Huancayo and Watheroo observatories concerning the nature of the radio "fade-out" effect indicates that this phenomenon is predominantly due to an intense ionization between heights of about 60 and 100 km. A definite magnetic effect is observed during the fade-out. An analysis by McNish at this Department of the magnetic effect shows it to be an augmentation of the magnetic diurnal variation as contrasted with other types of magnetic disturbance. The association of a magnetic effect of the diurnal-variation type with a definite region of the ionosphere through experimental observation forms a contribution of first importance to the science of terrestrial magnetism. The simultaneity of the fade-out, magnetic, and earth-current effects with solar outbursts in this region of sunspot-areas was confirmed by direct observation at the Huancayo Magnetic Observatory. Thus a new and productive field of speculation has been opened to theoretical advance.

Theoretical considerations have long pointed to an electrified upper atmosphere as the seat of magnetic disturbance and variation. With this in view, the Department initiated an experimental approach to problems of the outer atmosphere (the ionosphere) in 1925, when direct experimental evidence of ionized regions in the outer atmosphere was obtained. Subsequent experiments showed the distribution of this ionization to be complex. Advances in experimental technique have permitted formulation of more exact ideas as to the location, nature, and characteristics of the ion-banks which exist there. The association of a particular region of the ionosphere with a magnetic effect of the diurnal-variation type therefore represents a definite advance toward the original objective of examination of theoretical concepts of these phenomena by experimental methods.

Continuance of the program of recording permitted formulation of more concrete ideas as to the variation of ionization in the outer atmosphere. Of the changes observed, the change with the sunspot-cycle is now becoming apparent. This change has been large; in fact, it appears that the relation of ionospheric ionization to sunspot-number may be one of the closest solar and terrestrial relationships yet found.

With the completion of continuously recording equipment for determination of ionization throughout the ionosphere, further evidence as to the nature of the electrified particles in the various regions was obtained. A limiting value can now be placed on the ratio of electrons to ions of atomic or molecular size in the *E*-region (at about 100 km). This restriction aids greatly in determining the physical processes involved in the ionosphere and in the selection of proper theoretical ideas concerning terrestrial magnetism. The records from this new equipment have presented new, and



heretofore unsuspected, problems in the study of the ionosphere, at the same time providing many experimental data for their solution.

The program of ionospheric investigation was carried on by Berkner and Wells at Washington, Stanton at the Huancayo Magnetic Observatory, and Seaton at the Watheroo Magnetic Observatory.

#### RESULTS

*Analysis of the fade-out effect*—The radio fade-out effect can be studied advantageously from the continuous fixed-frequency records obtained at the observatories. The effect appears as a diminution or disappearance of echoes from the ionosphere. Following the inception of automatic recording at the Department's observatories, 148 fade-outs were observed at Huancayo (June 1935 to February 1937) and 49 at Watheroo (October 1936 to February 1937). The evidence indicates that the effect is an absorption of the radio wave in the region below about 100 km. The mechanism appears to be an increase of ion-density in this region of high collisional frequency, leading to the dissipation of radio waves which usually penetrate the region below about 100 km without appreciable loss. Investigation of the effect shows general agreement with the points made by Dellinger except as concerns the periodicity of the effect. Fade-outs occur only in the sunlit hemisphere, and are most intense within about  $30^\circ$  of the subsolar point. They have appeared with increasing frequency with the increase of sunspot-number: the correlation between monthly numbers of fade-outs and sunspots is  $+0.53 \pm 0.10$  for the data from Huancayo. This is probably the reason why the effect has passed so long unnoticed. The evidence supports Dellinger's hypothesis of the origin of these effects in the bright chromospheric eruptions; several coincidences were observed at the Huancayo Magnetic Observatory, where all phases of the effect were recorded. There is a strong tendency for fade-outs to be grouped. When one appears it is often followed by a series of fade-outs which occur around the Earth in the sunlit hemisphere. The beginning of a fade-out is essentially coincident at all stations within the probable limit of time-determination. The duration of fade-out is generally short: more than 60 per cent of fade-outs last less than 15 minutes, and the shorter ones are doubtless unrecognized by communication-services. The data are not yet sufficient to establish any tendency toward recurrence or quasi-recurrence at definite intervals. When the evidence collected by the National Bureau of Standards is considered, together with the determination of long-wave reflecting heights by Best, Ratcliffe, and Wilkes, it is seen that the lower limit of the effect must extend down to 60 or 70 km. Therefore, it may be supposed that the absorption of the radio wave occurs in this region because of the increase of ion-density contingent upon the absorption of the ultra-violet light from chromospheric eruptions.

*Characteristics of the ionized regions*—Further study was directed toward the diurnal, seasonal, and long-time changes of ionization of the major regions, as well as unusual effects which have been observed. The increase of ionization of all regions with the advance of the sunspot-cycle was pronounced. Since the sunspot-minimum in 1933–1934, the increase in the

mean noon value of ion-density in the  $E$ - and  $F_1$ -regions (at heights of about 100 and 200 km, respectively) was more than 45 per cent, while in the  $F_2$ -region (above 280 km) it was more than 250 per cent.

The annual change of ionization in the  $F_2$ -region which was reported last year has continued. The highest value of ion-density occurred during April at Watheroo as compared with February at Washington. A definite minimum in average values of  $F_2$ -region ion-density occurs at Washington, Huancayo, and Watheroo during July. Similarly, higher values are observed at all stations between October and April, with a secondary minimum around December. The greatest range of day-to-day values is found at Watheroo near December, so that the average values at Watheroo at that time tend to be lower than at other stations, but the highest individual values are observed at all stations between October and April.

An analysis of the sporadic ionization of the  $E$ -region showed this effect to be apparent at Huancayo for only about 6 hours out of some 8000 hours of observation. At Watheroo the effect is about 70 times as pronounced. The location of Huancayo on the magnetic equator relative to Watheroo far south of the magnetic equator suggests the possibility of magnetic control of this effect. The conclusion is reached that sporadic  $E$ -region ionization is not due to the electric fields associated with thunderstorms, as has been proposed by some investigators.

*Polarization of downcoming radio waves*—Records obtained with the completed automatic recorder at the Kensington Experimental Station show the "o" and "x" wave-components from the  $E$ -region to be completely resolved. Measurement of the separation of the critical frequencies for these components shows that reflection of the radio wave is primarily due to electrons. Using the method developed at the Department, the ratio of electrons to ions of atomic or molecular size must be greater than  $10^{-3}$  for the observations to date at the level of maximum electron-density of the  $E$ -region. This determination bears directly upon the concepts of current-flow and diamagnetism in this region of the ionosphere.

*Solar eclipse of June 8, 1937*—Complete data concerning the ionospheric changes were obtained at the Huancayo and Watheroo observatories during the solar eclipse of June 8, 1937. The eclipse was about 98 per cent total at the Huancayo Magnetic Observatory. Observations at Huancayo served to disclose the changes during the eclipse-period, while control-observations at the Watheroo Magnetic Observatory determined the relative normality of the eclipse-period. The analysis of the data is not yet completed. The data will throw light, however, on the little-understood behavior of the  $F_2$ -region.

*Radio wave-propagation*—The problem of wave-propagation in the ionosphere not only is of interest in communications, but basically underlies the methods by which the physics of the ionosphere is determined. Advances in this direction have, therefore, both practical and theoretical importance. Because of the seasonal asymmetry of  $F_2$ -region ionization in the Northern and Southern hemispheres, as determined at the Huancayo and Watheroo observatories, a corresponding asymmetry must be expected in the use of high communication-frequencies. A study of this effect shows

that in general higher frequencies can be used during the interval from October to April than during the remainder of the year in both hemispheres. Similarly, conditions for the higher communication-frequencies are more uniform in the Southern Hemisphere throughout the year. The effect is doubtless partially masked at present by the rapid change of ionization with sunspot-number, but is large enough to be of importance in communication-work. Studies are also in progress to determine the cause of the discrepancy between observed maximum communication-frequencies and corresponding values calculated from the vertical-incidence measurements.

*Recording of data*—The automatic fixed-frequency ionospheric recorder was placed in operation at the Watheroo Magnetic Observatory in October 1936, and continuous registration on a frequency of 4.8 mc/sec has been maintained since then. Continuous registration of ionospheric effects was maintained also at the Huancayo Magnetic Observatory on the same frequency throughout the year. In addition, a series of measurements involving about 20 hours per week was made manually on Mondays, Wednesdays, and Fridays at both observatories throughout the year. These observations were made at hourly intervals through the whole frequency-spectrum from about 2.5 to 14.0 mc/sec including all frequencies on which reflections were observed, with observations spaced from 0.1 to 0.2 mc/sec apart in frequency. All observations were photographically recorded and numerical reductions of these records were made at the observatories. Analyses of these data are practically complete and have appeared from time to time in published papers. The various studies here reported are based on the data obtained from these observations.

*Cooperative endeavor*—Because of the world-wide aspects of ionospheric investigations, close cooperation has been maintained with observers throughout the world. At the Edinburgh Assembly of the International Union of Geodesy and Geophysics, attended by Fleming and Berkner, a new committee on the ionosphere was appointed by the Association of Terrestrial Magnetism and Electricity to act jointly with the International Scientific Radio Union. Professor Appleton was designated as chairman and Berkner as secretary. The purpose of this committee is to encourage and suggest methods of interchange of data and information concerning the rapidly advancing technique of measurement, and to act in an advisory capacity in suggesting desirable experimental and theoretical problems and locations for measurement.

Advances in experimental and theoretical methods were studied by Berkner at the Conference on Atmospheric Ozone at Oxford, at the Slough Station of the National Physical Laboratory at London, at the Chelmsford Laboratory of the Marconi Company, at the laboratories of Cambridge University, and at the Halley Stuart Laboratory, all in England; and at the Heinrich Hertz Laboratory at Berlin, the Technische Hochschule at Munich, and the related laboratory of Professor Zenneck at Kokel in Germany.

The prospect of data from Fairbanks, Alaska, was advanced when President Bunnell of the University of Alaska, in cooperation with the Department, obtained the necessary radio-station license for ionospheric measurements at Fairbanks. Professor E. H. Bramhall, head of the Department of



Physics, University of Alaska, is supervising completion of the necessary equipment for manual multifrequency measurements. This program should prove invaluable to the understanding of ionospheric problems.

Following the ionospheric studies made at the Department last year by Professor C. T. Kwei, a manual multifrequency equipment was constructed by the Department and sent to Professor Kwei at Central China College, Wuchang, China. Observations in this location, having the same longitude as Watheroo but being in the Northern Hemisphere, are of the utmost importance in determining the pattern of  $F_2$ -region phenomena. At the end of June the equipment had just been received at Wuchang and the installation was under way.

Through cooperative arrangement with the National Bureau of Standards, exchange of ionospheric data between the Department and the Bureau is being maintained.

The third annual Conference on Ionospheric Research was held at the Department on May 1, 1937. The Conference developed as an outstanding feature the importance of close cooperation, both intellectual and material, between the various branches of science which have a bearing on the outer atmosphere of the Earth. Radio, terrestrial-magnetic, solar, and ozone studies as well as the fundamental processes of physics and chemistry are all intimately connected with the ionosphere; each has important contributions to make and each can derive valuable information from the others which might be otherwise unattainable. The Conference was fortunate this year because representatives of all of these branches of science attended, a number of whom are preeminent in their respective fields. The subjects treated were as follows: (1) measurements of magnetic activity for correlation with radio data; (2) short-time reflection of radio waves; (3) radio fade-outs and their relation to other phenomena; (4) developments in methods of investigation; (5) methods for more complete exchange of radio data; (6) relation of ionospheric investigations to problems of radio transmission.

A number of distinguished visitors from foreign laboratories were guests at the Department during the year to study methods of ionospheric investigation and the data obtained. These included Professor S. K. Mitra, University of Calcutta, India; Professor M. N. Saha, Allahabad University, India; Professor V. A. Bailey, University of Sydney, Australia; Dr. D. M. Myers, Australian Radio Research Board; and Dr. J. T. Henderson, Canadian Radio Research Board. Arrangements were completed for Dr. H. G. Booker, of Christ's College, Cambridge University, England, to work at the Department on theoretical problems concerning the ionosphere during his sabbatical year. Dr. Booker has made notable contributions to the knowledge of propagation of waves in the ionosphere at oblique incidence in the presence of the Earth's magnetic field.

#### PUBLICATIONS

Publications relating to the above investigations are noted in the Bibliography given elsewhere in this Year Book.

"The electrical state of the Earth's outer atmosphere" was the subject of



a lecture presented by Berkner at the Carnegie Institution of Washington on February 2, 1937. Berkner spoke on "Ionospheric research and the first Byrd Antarctic Expedition" on January 6, 1937, before the George Washington University Section of the American Institute of Electrical Engineers. At the joint meeting of the Institute of Radio Engineers and the International Scientific Radio Union held at Washington, April 30, 1937, Berkner and Wells discussed "An asymmetry between the Northern and Southern hemispheres in wave-propagation in the ionosphere." Other lectures by Berkner included: "Earth, radio, and the Sun," at the Cosmos Club, Washington, March 8, 1937; and "Engineering aspects of polar exploration," at the annual banquet of the Engineers' Council, George Washington University, May 8, 1937. Wells represented the Department at the Silver Anniversary Convention of the Institute of Radio Engineers, New York, May 10 to 13, 1937.

#### INSTRUMENTAL DEVELOPMENTS

*Automatic multifrequency equipment*—Following completion of the development of an automatic multifrequency ionospheric recorder, reported last year, the construction of the first of these units for use at the observatories was completed in the instrument-shop during the year. This unit records continuously the virtual height of waves of frequencies between 0.516 and 16.0 mc/sec during successive 15-minute intervals. The radio license for operation of this unit is probably the most inclusive ever issued, and was obtained after exhaustive engineering tests. Operation is continuous, 96 records of the virtual heights of equivalent electron-densities between 3000 and 3,000,000 per cubic centimeter being obtained each day. Thus rapid ionospheric changes can be followed in detail. Extensive tests have demonstrated the reliability of the equipment and the noninterfering quality of the emission. Construction of a second unit of the same design is well advanced. These two units will be installed at the Huancayo and Watheroo observatories during the ensuing year. Single-frequency recording and manual observation will then be replaced, making additional time available for the study of the much more complete multifrequency records.

Completion of this equipment represents introduction of one of the most promising and productive fields for ionospheric investigation so far devised. Much credit must be given to Steiner and his associates in the instrument-shop for the precise instrumentation and ingenious devices designed and constructed for this equipment. Operation during test has already shown certain characteristics of the ionosphere hitherto unsuspected.

*Kensington Experimental Station*—Operation was continued at the Kensington Experimental Station of the Department near Kensington, Maryland, throughout the year under radio licenses W3XI and W3XFE. Continued occupancy of this station was possible through the courtesy of Colonel M. K. Barroll, U. S. A. (retired), who maintains an active interest in this work. Additional construction was necessary to permit continued development and calibration of the automatic multifrequency equipment. This included extension of floor-space and erection of antennas having the necessary low characteristic impedance.

## MAGNETISM AND ATOMIC PHYSICS

## THE STRUCTURAL FORCES OF ATOMIC NUCLEI

The development of the laboratory-program on the fundamental aspects of magnetism included the further extension and testing of the observations and conclusions described in last year's report. These had given, for the first time, direct information regarding the nature of the intensely localized forces which bind together the components of all atomic nuclei. These components are protons (familiar as the positively charged nuclei or "cores" of ordinary hydrogen atoms) and neutrons (similar to protons, but having zero electrical charge). The binding forces which hold them together, forming the nuclei of all heavier atoms, are neither gravitational nor electrical nor magnetic in character, although possibly all these four universal forces are distinctive expressions of some one basic unity of all matter. This is a problem for the future, but the physicists of today have discovered inside of atomic nuclei and are examining a basic simplicity and unity in the physical world which is exceedingly far-reaching and important. The Department's contribution in nuclear physics has proved a decisive factor in this development.

It was foreseen that direct measurements at various energies and in various angles of the "billiard-ball collisions"—technically called the scattering—of protons on protons would serve to determine experimentally which one of the various theoretical possibilities concerning the nature of these fundamental forces might be correct, or, more probably, would serve as the experimental basis for a new theoretical concept. These anticipations have been justified. The experiments already have served as a selection criterion for the rejection of theoretical views previously considered acceptable and have given rise, in the hands of Dr. Breit and his associates, to a theoretical interpretation emphasizing a hitherto un hoped-for unity of matter, namely, that the several possible interactions among the primary nuclear particles (proton-proton, proton-neutron, and neutron-neutron forces) are almost identical. It is surprising enough that no repulsions appear, and hence still more unexpected that these forces are not only alike but practically equal.

Such theoretical generalizations require years of research for adequate test and development, but during this report-year a simple and direct test was made which verified experimentally, in a new and striking way, one of the important qualitative aspects of last year's conclusions. This is that the proton-proton interaction is an *attraction* (and not a repulsion) which sets in abruptly at very close distances of approach. This interpretation is practically independent of any explicit theory of nuclear dynamics. The experiments, difficult of execution but simple enough in conception, determined the distance of approach (energy of proton-beam) at which the well-known electrical forces of repulsion between two protons are *exactly canceled* in their effect on the motion of the protons by the "new" force of attraction. At greater distances between protons the former, and at lesser distances the latter, force predominates and gives rise to scattering, but

at this one critical value of proton-beam energy (or distance apart) no scattered particles are observed.

On the basis of the Department's measurements last year, Dr. Breit and his associates predicted that this minimum of scattering should appear at energies of approximately 400 kilovolts. It is significant evidence of the essential correctness of the whole body of measurements that the expected minimum was found at approximately 430 kilovolts. Measurements on the scattered protons were made at intervals from 650 to 230 kilovolts and for  $5^\circ$  intervals between  $20^\circ$  and  $50^\circ$ , using a Geiger point-counter instead of the linear amplifier used last year. A new scattering apparatus was constructed and used for somewhat better specification of angles than before. As a further rough check on last year's observations, measurements also were made at  $25^\circ$  and  $45^\circ$  for voltages from 600 to 900 kilovolts, using the Geiger counter. The agreement with the previous linear-amplifier measurements was not entirely satisfactory, a slightly greater increase of scattering with voltage being found, but the difference is not significant to the interpretation of the measurements, since the Geiger counter is to be considered a qualitative rather than a strictly quantitative instrument in this application. Thus the Department's demonstration last year of the existence of a strongly attractive proton-proton interaction is confirmed independently.

Further quantitative measurements on proton-proton scattering in the energy-region above 600 kilovolts are now being made, using two linear amplifiers for the observations, one of which serves for continuously monitoring the proton beam-current by counting the protons scattered from a very thin gold leaf. Quantitative measurements at considerably higher voltages are needed for the specification of more detailed aspects of the proton-proton interaction.

#### ARTIFICIAL NEUTRON-SOURCES

Interest has been aroused in biological and chemical circles as well as among physicists regarding the possible future applications of the intense neutron-sources now becoming available from transmutations produced at high voltages. Besides its intrinsic properties as a penetrating radiation which produces ionization, neutron-bombardment gives rise to artificial radioactivity in nearly all the elements in the atomic table. Such artificially unstable atoms may be used as extremely sensitive and reliable "tracers" for following these elements through biological or chemical reactions of any degree of complexity, and the radioactive elements may conceivably have therapeutic uses if produced in sufficient quantity.

With regard to the intensity of the neutron-emission from each of several common nuclear transmutations, only very crude estimates (most of them in error by more than a factor of 10) were available until a series of measurements were made here last autumn. Dr. E. Amaldi, of the Royal University of Rome, took part in these measurements, which utilized the quantitative technique of neutron-measurement developed by Amaldi and Fermi. This involves measuring the neutrons after they are retarded to thermal velocities; measurements are made throughout a large tank of water and the result



obtained by integration, correcting for the capture of the neutrons by the hydrogen in the water.

These measurements of the neutron-yields from four common reactions at various voltages were made directly comparable to the Rome measurements using radium. Expressed in these terms, it was found, for example, that one microampere of deuterons bombarding beryllium at 1,000,000 volts produces the same number of neutrons per second ( $1.7 \times 10^8$ ) as are produced by 6750 millicuries of radium bombarding beryllium. If these neutrons are used in turn for producing artificial radioactivity, a source of strength approximately 0.7 millicurie may be approached under the best conditions. A rough comparison with the Berkeley cyclotron (comparing readings of Victoreen dosimeter) indicates that at five or six million volts the neutron-intensity per microampere of deuterons on beryllium is about 100 times greater. All other neutron-sources appear less intense, possibly excepting lithium, which is of the same order as beryllium at 1000 kilovolts. The approximate currents and voltages necessary for producing any desired neutron-intensity, especially as required for chemical or biological experiments, accordingly are now known from these measurements.

The radiation from beryllium under deuteron-bombardment is a mixture of neutrons of all velocities with gamma rays of various energies. Cooperative experiments with Dr. M. Demerec, of the Institution's Department of Genetics, have been in progress for more than two years seeking to determine some of the genetic effects of neutron-irradiation. The disentangling of the numerous physical and biological factors, especially in view of the mixed radiations emitted from these neutron-reactions, is a complicated problem. Simple generalizations regarding the effects of neutron-irradiation cannot yet be made.

#### THE TRANSMUTATIONS OF LITHIUM

A series of precise measurements on the several transmutation-reactions of lithium—hitherto accepted as well known and in fact as the classic examples of such transmutations—led during the year to the discovery of a unique new heavy-particle transmutation-process. This unexpectedly and quite explicitly involves the crucial difficulty (apparent nonconservation of energy) hitherto associated only with light-particle (beta-ray) transmutations. These measurements were undertaken to illustrate and test the precision technique which the Department has spent some years in developing. The new reaction, predicted by the Department's investigators on the basis of their precision measurements reported last year and subsequently first observed in Cambridge, involves the emission of delayed alpha particles from  $\text{Li}^8$  following deuteron-bombardment of  $\text{Li}^7$ . These alpha particles show a continuous energy-distribution, and analysis shows that they are accompanied by a simultaneous beta ray. The conservation of energy fails for this unusual heavy-particle process in just the way it fails for beta-ray transmutations; in other words, this heavy-particle process exhibits the same crucial difficulty as hitherto found solely in beta-ray transmutations, a difficulty verbally "solved" by the hypothesis of a new particle of very small mass and zero charge called the *neutrino*.



Discovery of this new process gives a sound basis for hope that independent evidence for the existence of such a particle may be obtained by examination of the *momentum* of the particles involved; the two types of observation should show whether or not a fourth body (the neutrino) is associated with each explosion of a  $\text{Li}^8$  nucleus into the two alpha particles and a beta particle. Experiments toward this end are in progress.

The lithium-reaction studies were undertaken jointly by the Department's staff and by Dr. L. H. Rumbaugh, of the Bartol Research Foundation, who spent four months here. Dr. Rumbaugh supplied the specially prepared targets of the separated isotopes of lithium ( $\text{Li}^6$  and  $\text{Li}^7$ ), obtainable only by means of his mass-spectrograph at the Bartol Research Foundation, when these were needed for precision or clarity of the results. In addition to the delayed alpha particles, extended studies were made of the identity, energy, variation with voltage, and absolute yield of eight or nine other reactions of the two lithium isotopes when bombarded separately by the two hydrogen isotopes. Dr. R. B. Roberts, of Princeton University, guest investigator and subsequently Carnegie Institution Fellow here, worked with the staff and Dr. Rumbaugh in these investigations.

#### THE ATOMIC-PHYSICS OBSERVATORY

A major development, which will be of great importance to the future of the Department's program, was the beginning of the construction of a long-needed high-voltage equipment of considerable size, with associated facilities—a project which has been given the name "Atomic-Physics Observatory." The large steel tank with its surrounding building and underground tunnels and vaults resembles an astronomical observatory in outward appearance. The designation "observatory" is not without justification in view of the smallness of the regions of space to the study of which the equipment is dedicated—regions whose remoteness from ordinary dimensions and conceptions of size require astronomical magnitudes for their expression. The construction of the observatory, of which Major F. T. Norcross was engineer, was begun on May 20 by Contractor Raymond H. Burrows, who completed the substructure in July; the steel pressure-vessel is to be constructed by the Chicago Bridge and Iron Company.

The new equipment will consist of a large electrostatic generator and vacuum-tube enclosed in a pear-shaped steel vessel 55 feet high and 37.5 feet in diameter at the upper end. Air in the vessel is to be compressed to 50 pounds per square inch for electrical insulation of the generator and tube, which are designed to operate under precise control at potentials exceeding 5,000,000 volts. An underground tunnel-maze and control-room surrounded on all sides by earth for shielding of operators and instruments against X-rays and neutrons has been provided. This new installation, crystallized in the design of this equipment three years ago, has been looked forward to for several years. It embodies, on a moderate but adequate scale, the numerous technical developments looking toward analytical and precise observations evolved by the Department's studies over many years on the application of high voltages to nuclear-physics problems. Together with a similar equipment being erected at the Westinghouse Research Labora-

tories under the direction of a former associate of our staff, Dr. W. H. Wells (see report for 1934-1935), this installation is unique in the many opportunities it presents for future studies in the rapidly developing field of nuclear physics.

#### THEORETICAL-PHYSICS CONFERENCE

A third Conference on Theoretical Physics under the joint auspices of the George Washington University and of the Institution, acting through this Department, brought to Washington twelve outstanding investigators in theoretical physics for a "working conference" extending throughout the week February 15 to 20, 1937. The sessions were devoted to current problems which relate to the properties and interactions of the elementary material particles, together with related problems on the structure of atomic nuclei.

A vital point at the present time is the question to what extent calculations on the mechanics of the nucleus properly can be made using the ideas and methods already developed and successful in the treatment of the external structures of atoms. Professor Bohr addressed the conference on calculations of this type, stating that they may be based on an unjustifiable analogy; he proposed instead a model of the nucleus which is simpler in conception, though perhaps less amenable to calculation, by comparing it to a liquid droplet. The vibrations and evaporation of such a droplet have been treated in classical theory, and Professor Bohr suggested that similar calculations should be applied to nuclear processes. The applicability and usefulness of either or both of these methods in the analysis of nuclear dynamics remains to be seen.

The plan of these conferences has been to build up in this country something similar to the Copenhagen conferences which have grown up around Professor Bohr; in these a small number of theoretical physicists working on related problems assemble to discuss informally the fundamental or critical difficulties met in their researches. Such conferences have proved exceedingly fruitful. The rapid development in physics during recent years has made it imperative that a close relationship be maintained among the various investigators, and between experimental and theoretical developments. These Washington conferences have made significant contributions.

#### MISCELLANEOUS

Some preliminary tests were made in the laboratory regarding details of the new method for studying the high atmosphere using a modulated searchlight-beam, mentioned in reports of the last two years. This suggested method has assumed particular importance during the past year through the establishment of the fact that the diurnal variation of terrestrial magnetism originates in the lower portion of the ionosphere.

Those of the staff engaged in the nuclear-physics studies were Hafstad, Heydenburg, Meyer, Schmidt, and Tuve, with Dr. E. Amaldi, of the Royal University of Rome (September 12 to October 5), Dr. L. H. Rumbaugh, of the Bartol Research Foundation (March 10 to June 30), and Dr. R. B. Roberts, of Princeton University (January 23 to June 12), as guest

investigators. Numerous conferences with Professor Breit, of the University of Wisconsin (research associate), and with Professors Gamow (research associate) and Teller of George Washington University, were of great value in furthering the progress of these studies.

#### PUBLICATIONS

Publications relating to the above investigations are noted in the Bibliography given elsewhere in this Year Book.

Formal talks were presented as follows: Harvard Tercentenary Conference on Arts and Sciences, September 8, 1936, by Tuve on "Proton scattering"; Department of Genetics, Cold Spring Harbor, October 29, 1936, by Tuve on "Nuclear forces and radioactive atoms of various elements as tracers of chemical and biochemical reactions"; Physics Colloquium, George Washington University, December 16, 1936, by Hafstad on "Neutron-sources"; Cancer Symposium of American Association for the Advancement of Science, Atlantic City, December 29, 1936, by Tuve on "High-energy radiations and their applications"; American Association for the Advancement of Science, Atlantic City meeting, December 1936, by Hafstad on "Neutron-yield curves for light elements"; Washington, D. C., before a group of radiologists, January 11, 1937, by Tuve on "High-energy radiations"; Physics Colloquium, Catholic University, Washington, D. C., January 27, 1937, by Hafstad on "Nuclear-physics investigations of the Department of Terrestrial Magnetism"; Philosophical Society of Washington, February 13, 1937, and National Bureau of Standards, March 19, 1937, by Tuve and Hafstad on "Structural forces within atomic nuclei"; Philadelphia Physics Club, February 20, 1937, and Philadelphia Physics Colloquium, May 20, 1937, by Hafstad on "Structural forces in atomic nuclei"; American Institute of Electrical Engineers and faculty, University of Maryland, February 25, 1937, by Tuve on "Supervoltages and their application to nuclear physics"; Biochemical Foundation of Franklin Institute, June 2, 1937, by Hafstad on "The production of artificially radioactive substances and their uses in chemistry and biology."

#### COOPERATION IN NUCLEAR PHYSICS AT UNIVERSITY OF WISCONSIN

Professor G. Breit, of the University of Wisconsin, continued as research associate and consultant in the nuclear-physics program. The following paragraphs summarize briefly the theoretical and experimental work done by him and his associates at the University of Wisconsin.

The analysis of data on scattering of protons by protons was completed and prepared for publication. The outcome of this work was the determination of magnitude of attraction between protons making head-on collisions. This attraction turned out to be practically equal to although slightly smaller than the attraction between proton and neutron colliding head-on with spin-orientations similar to those that occur between protons. This coincidence suggested the hypothesis that in first approximation the interactions between nuclear particles are equal, so that nuclei are treated now using the *symmetric Hamiltonian* as a starting point. The conditions which are necessary to avoid collapse of heavy nuclei have been investigated in collaboration with Feenberg.



The neutron-proton interaction in the singlet  $S$ -state is known primarily from experiments by Amaldi and Fermi and the theoretical work of Fermi. The validity of the symmetric Hamiltonian depends essentially on the correctness of the conclusion that the singlet level is virtual. Some of the evidence for this view has been examined quantitatively in collaboration with Stehn. The preponderance of evidence is for the virtual level hypothesis.

*Fine structure and relativity*—The question of the fine structure of nuclear levels was examined. The qualitative considerations of Inglis and Furry about the behavior of single particles have indicated that a suitable theory of relativistic effects in the interaction of many particles had to be formed. This was done, and it was found possible to account satisfactorily for the facts observed and investigated so far. The application of the theory to experimental material on fine structure is in progress in collaboration with Stehn.

The approximately relativistic theories have indicated the probability of interactions between spins of protons and neutrons that depend on distance in a manner different from that of the forces which do not depend on spin-orientation. The approximate magnitude of these spin-dependent potentials is similar to the empirically known energy-difference of the deuteron in its lowest singlet and triplet states. In the equations tried the theoretical difference is opposite to the empirical. The latter developments were carried out in collaboration with Share.

Extensions of the theory to exchange interactions and to high relative velocities have been carried out and are in progress.

$Li^8$ —The discrepancy in limit of continuous beta spectrum of  $Li^8$  and of mass-difference of  $Li^8$  and  $Be^8$  was interpreted in collaboration with Wigner as being due to the operation of a beta-ray selection rule which does not allow  $Li^8$  in its  $^3P_2$ -level to dissociate into  $Be^8$  in  $^1S_0$ -level, but allows it to go into  $Be^8$  in  $^1D_2$ -level.

Quantitative work on data obtained by Hafstad, Roberts, and Rumbaugh is in progress. It supports in the main the original hypothesis. Some evidence for effects of  $Li^8$ -like levels of  $Be^8$  has been found.

*Nuclear reactions*—The following points about nuclear reactions have been communicated to others and may be found of interest. The radiative capture of protons by  $C^{12}$  to form  $N^{13}$  can now be explained as being due to resonance to the F-level of  $N^{13}$ , from which the system falls by a quadrupole jump to the P-level of  $N^{13}$ . Dipole radiation cannot occur, and the previous difficulty of too little observed yield (observations of Department of Terrestrial Magnetism) disappears.

The resonance to protons of 180-kilovolt energy in the emission of alpha particles from boron observed by the Minnesota group, and the resonance to protons at a higher voltage in the emission of gamma rays observed by Herb, Kerst, and McKibben, can be explained as being due to levels of  $C^{12}$  similar to the normal levels of  $B^{12}$ . One expects, in all, four closely spaced levels,  $^1P_0$ ,  $^3P_2$ ,  $^3P_1$ ,  $^3P_0$ , of which two have been found so far. The agreement of this explanation with current values of the masses is quite good.

The very high yields of gamma rays under proton-bombardment of fluorine can be explained only by supposing that the yield is determined by



probability of alpha disintegration and that the gamma rays are emitted by oxygen.

## FIELD-WORK AND REDUCTIONS

### LAND MAGNETIC SURVEY

The Section of Land Magnetic Survey has maintained observation, collection, compilation, and discussion of data relative to the magnetic field of the whole Earth. Because of limited funds available for the survey, only a modest amount of field-work was done this year by the Department. Green continued as Chief of Section while in charge of the Watheroo Magnetic Observatory, with the help in the office of Duvall and Wallis for full time and of Ennis, Forbush, and Johnson for part time. Parkinson, of the regular staff, continued in the field in Australasia and the Pacific Islands. Brown, of the temporary staff, did some work in China. Professor L. Slaucitajs, guest physicist from the University of Riga, also assisted in compilations and discussions while receiving instruction in the technique of observation and computation.

Cooperation with the Aerial, Geological, and Geophysical Survey of Northern Australia was continued through the loan of magnetometer-inductor 18, and with the Adelaide Observatory of South Australia through the loan of magnetometer 6. Cooperation with the University of Cape Town was continued through the loan of magnetometer-inductor 17. Dr. A. Ogg, in charge of the Observatory for the University, has utilized this equipment and material supplied by the Department in his work as Magnetic-Survey Adviser in the establishment of the Magnetic Branch of the Trigonometrical Survey Office of the Union of South Africa. Arrangements were made with the Gulf Research and Development Company whereby V. Vacquier of that company received training September 18 to 22, 1936, in magnetic methods and instruments. Universal magnetometer 21 and inductor 171 were loaned for use in the company's field-work for magnetic measurements in the region of the Persian Gulf. Special directions were furnished, as also descriptions and sketches of each of the Department's magnetic stations in that general vicinity.

Arrangements were completed for cooperation in securing magnetic data in the Arctic through the loan of instruments and the preparation of instructions and directions for the MacGregor Arctic Expedition of 1937-1938 on the schooner *General A. W. Greely*, which left Newark, New Jersey, July 1, 1937. R. G. Fitzsimmons of that expedition was given instruction in observational methods and computations at Washington during two weeks in June. Preliminary arrangements were made in a conference with Sir Hubert Wilkins for cooperation in obtaining magnetic observations during his proposed submarine expedition to the arctic regions in 1938. A. Hizon, of the Philippine Islands Coast and Geodetic Survey, was instructed in the methods of observing with a magnetometer-inductor and in computations of such observations preparatory to his magnetic-survey work in the Philippines.

The revisions and compilations of the land magnetic observations obtained

by the Department since the publication of volume VI are well under way. The seventeen cahiers of observations obtained in Kenya, Uganda, Anglo-Egyptian Sudan, and Belgian Congo in cooperation with E. C. Bullard, of the Department of Geodesy and Geophysics of the University of Cambridge, from November 1933 to February 1934 were received for final revision. Observations at four stations (Ardrossan, Maitland, Yorketown, and Edithburg) occupied in March 1936 by A. E. Markey, of the Adelaide Observatory, and not noted in last year's report were received.

Least-square adjustment of the observations of magnetic declination in the Pacific by the *Galilee* and *Carnegie* to determine secular variation in that element was concluded by Duvall, who had the assistance of Ennis from January.

#### FIELD-OPERATIONS AND COOPERATIVE SURVEYS

Brief accounts of field-operations referred to above are given in more detail in the following paragraphs.

*Africa*—Secular-variation data were obtained through control-observations at the Observatory of the University of Cape Town.

*Asia*—The only field-work in Asia was that performed by F. C. Brown in July 1936 prior to his departure for the United States. Following monthly observations at the Wuchang station on July 11, 1936, during July 20 to 22 he compared magnetometer-inductor 13, which has been in use in China for a number of years, with the standards of the Zosé Observatory. He shortly afterward sailed for America, bringing with him the instrument for determination of corrections on standards and for a thorough overhauling before resumption of field-work in China late in 1937.

J. T. Murrell and O. Wendenberg, of the Gulf Research and Development Company, completed observations during May 1937 at Madaniyat, Bahra, Gahlula, and Kuwait in Kuwait, Arabia, and at Basra and Baghdad in Iraq.

*Australasia and Pacific Islands*—Continuing the extensive program of field-work in Australasia and the Pacific Islands inaugurated early in 1936, and using Sydney, New South Wales, as a base, Parkinson completed five expeditions as follows: (1) Queensland and New South Wales, 11 stations, of which the last 4 (Rockhampton and Maryborough, in Queensland, Moree and Werris Creek, in New South Wales) were occupied in July 1936; (2) Victoria, Tasmania, etc., 6 stations: Toolangi Observatory (Victoria), Sorell and Longford (Tasmania), Wellington (New South Wales), Townsville (Queensland), and Makambo Island; (3) Solomon Islands, Bougainville Group, Bismarck Archipelago, New Guinea, New Ireland, and Papua, 15 stations: Meringe Lagoon (Ysabel Island), Gizo Island, Faisi Island, Numa-Numa, Teopasino, Rabaul, Salamaua, Madang, Lombrum, Boram, Wiewak, Kavieng, Pondo, Samarai, and Port Moresby; (4) New Zealand, 12 stations: Amberley, Clinton, Kingston, Queenstown, Roxburgh, Ekatahuna, Hobsonville (Auckland), Domain (Auckland), Te Awamutu, Rotorua, Opotiki, and Napier. Parkinson attended, January 12 to 16, 1937, the meetings of Section A (Mathematics and Physics) of the Australasian Association for the Advancement of Science, which were held in the Auckland University. During February 27 to March 3 Parkinson completed at Blacktown, New South Wales, intercomparisons between his magnetometer-inductor 28 and magnetometer-inductor 18, the instrument being used by Richardson of the Aerial, Geological, and Geophysical Survey of Northern Australia. (5) Nauru Island and Gilbert Islands, 6 stations: Nauru, Ocean Island, Nonuti Atoll, Tapeteuea Island, Arorai Island, and Apiang Island. Returning to Sydney April 30, Parkinson completed computation of field-results and made arrangements for intercomparisons of

magnetic standards at the Apia Observatory and for the redetermination of some of the constants of his instrument during June 8 to 25. He left Apia June 30 en route to Honolulu to compare his instruments with the standards of the Honolulu Magnetic Observatory and with magnetometer-inductor 13, which had been shipped to that Observatory en route to China. The last instrument was then forwarded to Dr. Ting, Director of the Research Institute of Physics, Academia Sinica, Shanghai, China, for later use in obtaining cooperative observations in northwest China and for intercomparisons of standards at observatories in China.

The usual control-observations for magnetograph base-lines were maintained at the Watheroo Magnetic Observatory.

*North America*—Many comparisons of instruments and determinations of their corrections on the International Magnetic Standards of the Department were made at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey. At that Observatory the Department's sine-galvanometer 1 was continued as the standard instrument in horizontal intensity. The instruments compared included magnetometer-inductor 111 constructed by the Precise Instrument Company for use by the British Admiralty's nonmagnetic vessel *Research*, magnetometer-inductor 13 upon return from China and after overhaul in the instrument-shop before its return to China via Honolulu, dip circles 222 and 242 and Berger theodolite compass 3578 for the MacGregor Arctic Expedition. In July 1936 standardization observations of the La Cour quartz-fiber horizontal-intensity magnetometers (designated as QHM) nos. 12, 17, and 18 were completed and those instruments were returned to Denmark via Japan, these observations being in connection with the world-wide comparison of magnetic standards in accordance with the plans for the committee to promote intercomparisons of magnetic standards later appointed at the Edinburgh Assembly of the International Union of Geodesy and Geophysics.

*South America*—Secular-variation data were obtained for the control-observations made regularly each week at the Huancayo Magnetic Observatory.

### OBSERVATORY-WORK

Johnston continued in charge of the Section of Observatory-Work. With the assistance of Miss Balsam, McNish, Forbush, and Ledig, the magnetic reductions and compilations were maintained. Wait and Torreson made excellent progress in the reduction of the atmospheric-electric data. The members of the staff in residence at the observatories are mentioned in their respective reports.

At Watheroo and Huancayo observatories continuous records were obtained of the three magnetic elements, of atmospheric potential-gradient, of positive and negative conductivity of the atmosphere, of earth-currents, of heights of the ionosphere using a fixed frequency, and of the meteorological elements. At the Huancayo Observatory there were also obtained continuous records with a three-component seismograph and a precision cosmic-ray meter as well as daily spectrohelioscopic observations during the assigned two half-hour periods. The cooperative work in atmospheric electricity was continued with the Apia Observatory of the Department of Scientific and Industrial Research of New Zealand. At Tucson, in cooperation with the United States Coast and Geodetic Survey, the program was continued in the atmospheric-electric and earth-current fields, the latter with the additional cooperation of the Bell Telephone Laboratories. At Cheltenham the United States Coast and Geodetic Survey operated the CIW vertical-in-



tensity induction-variometer during the year. The operation of the CIW sine-galvanometer maintained both the Department's and the Survey's standards in horizontal intensity.

The tabulations of magnetic character-numbers and daily magnetic characterizations from Watheroo and Huancayo observatories were forwarded regularly to the Commission for Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Organization. In March 1937 the Department began the weekly compilation of mean magnetic character-numbers telegraphed from seven American-operated observatories, namely, Watheroo and Huancayo of the Carnegie Institution of Washington, and Cheltenham, Honolulu, San Juan, Sitka, and Tucson of the United States Coast and Geodetic Survey. This compilation for each Greenwich half-day gives the character-numbers on a scale 0,  $\frac{1}{2}$ , 1,  $1\frac{1}{2}$ , and 2. The values are supplied weekly to Science Service, which distributes them to interested investigators and radio-communication companies for prompt use in correlation-studies. The average character-numbers of the seven observatories over a period of years show excellent relative agreement with the international character-numbers from a world-wide distribution of observatories. They have the advantage that they apply to the preceding week, whereas the international character-numbers are published at quarterly intervals and the publication necessarily cannot appear until some time after the completion of the quarter.

The Department cooperated with the MacGregor Arctic Expedition, 1937-1938, in supplying apparatus for a complete magnetic observatory, and in training an observer for the installation and operation of the magnetic equipment and for the reduction of the observations.

#### OPERATIONS AT OBSERVATORIES

The operations during the report-year at the observatories of the Department and at observatories with which the Department cooperated are summarized below.

*Watheroo Magnetic Observatory, Western Australia*—The Watheroo Magnetic Observatory is situated in latitude  $30^{\circ} 19' 1''$  south and longitude  $115^{\circ} 52' 6''$  east of Greenwich, 244 m (800 ft.) above sea-level.

The Eschenhagen magnetograph was operated continuously throughout the year with no loss of record. Following the adjustments incident to the aligning of the horizontal-intensity-variometer magnet in the magnetic prime vertical during March 1936 and the placing of a control-magnet on this variometer, the scale-value remained remarkably constant. Scale-value determinations by the deflection-method were made once each month.

Vertical-intensity scale-value observations were made daily by the electrical method. The monthly mean scale-values for both horizontal and vertical components for the calendar year 1936 are shown in table 1.

The La Cour rapid-running magnetograph was in continuous operation with the exception of short periods from time to time when the driving mechanism failed or when adjustments were necessary. Scale-value determinations by the electrical method were made monthly. The values for horizontal intensity were quite consistent; those for vertical intensity were also fairly consistent for the first half of the year but later developed irregular tendencies. During November the agates were cleaned and the instrument operated satisfactorily thereafter. Apparently the



trouble was caused by evaporation and recrystallization of the drying agent, forming needle-like crystals on the knife-edge bearings and supports. The scale-values derived from the monthly determinations are given in table 1.

The Mitchell vertical-intensity inductometer was in operation continuously. The times of sudden commencements of magnetic disturbances were determined from its records. Until August 1, 1936, the sensitivity of the galvanometer and the scale-value were determined weekly. Beginning August 1, these determinations were made but once monthly, as the consistency of the results over a number of years fully warranted less frequent determinations.

The preliminary mean values of the magnetic elements for all days of 1936, as deduced from the Eschenhagen magnetograms, referring the elements to the north-

TABLE 1—*Scale-values of magnetographs, Watheroo Magnetic Observatory, 1936*

Month	Scale-values in $\gamma/\text{mm}$			
	Eschenhagen		La Cour	
	<i>H</i> (reduced to base-line)	<i>Z</i> (means daily values)	<i>H</i>	<i>Z</i>
January.....	2.69	4.17	4.61	3.46
February.....	2.67	4.28	4.63	3.58
March.....	....*	4.16	4.67	3.12
April.....	2.35†	3.96	4.82	3.25
	2.34‡			
May.....	2.36	4.02	4.52	3.32
June.....	2.34	4.42	4.63	3.06
July.....	2.33	4.58	4.68	3.07
August.....	2.34	4.53	4.63	2.87
September.....	2.35	4.10	4.64	3.46
October.....	2.35	4.27	4.67	3.52, 3.63
November.....	2.34	4.26	4.58	3.60, 2.23
December.....	2.35	4.19	4.64	2.34

\* Under adjustment.

† April 8.

‡ April 14.

seeking end of the needle and reckoning east declination and north inclination as positive, are: declination,  $-3^{\circ} 37'1$ ; horizontal intensity, 0.24677 CGS unit; vertical intensity,  $-0.51412$  CGS unit; and inclination,  $-64^{\circ} 21'6$ . The preliminary values of the annual changes in the magnetic elements during 1935.5 to 1936.5 are: declination,  $+5'4$ ; horizontal intensity,  $+5$  gammas; vertical intensity,  $-32$  gammas; and inclination,  $-0'6$ .

Continuous records of earth-potentials for derivation of diurnal variation of earth-currents were made throughout the year over the system of electrodes as described in previous reports. A few scattered days were lost, but the total amount of record lost was negligible. Electrode R' failed during January 1936, and was renewed during April; the new electrode also failed during July and was rebuilt during August.

Air-potentials were recorded continuously with the standard potential-gradient apparatus as in former years and the "reduction-factor" was determined monthly as summarized in table 3. Table 2 gives the observed annual mean values of this "reduction-factor" for the past thirteen years.

Positive and negative air-potentials were recorded throughout the year and the

usual control-observations were made regularly. Table 3 gives preliminary values of the potential-gradient in volts per meter and of the conductivities in electrostatic units as recorded during complete days of 1936.

TABLE 2—*Observed annual mean values of reduction-factor, Watheroo Magnetic Observatory, 1924-1936*

Year	Factor	Year	Factor
1924.....	1.31	1930.....	1.11
1925.....	1.31	1931.....	1.12
1925*.....	1.16	1932.....	1.11
1926.....	1.16	1933.....	1.11
1927.....	1.11	1934.....	1.10
1928.....	1.14	1935.....	1.10
1929.....	1.12	1936.....	1.10

\* Radio mast removed April 6, 1925.

The narrow-sector directional atmospherics recorder, on loan from the Australian Radio Research Board of the Council for Scientific and Industrial Research, was kept in operation until October 25, 1936, when word was received that the Board had decided to discontinue its atmospherics work at least for the present. Until

TABLE 3—*Preliminary monthly mean values of atmospheric-electric elements, Watheroo Magnetic Observatory, 1936*

Month	Potential-gradient			Air-conductivity, unit $10^{-4}$ esu			
	Reduction-factor	Value for		Complete days	$\lambda_+$	$\lambda_-$	$\lambda_+ + \lambda_-$
		Complete days	In v/m				
January.....	1.09	17	103.4	14	1.63	1.49	3.12
February.....	1.10	10	128.8	8	1.42	1.30	2.72
March.....	1.12	10	103.3	11	1.56	1.50	3.06
April.....	1.11	13	73.0	19	1.98	1.93	3.91
May.....	1.12	19	65.9	18	2.20	2.02	4.22
June.....	1.12	24	70.1	24	2.37	2.18	4.55
July.....	1.12	24	79.0	26	2.28	2.00	4.28
August.....	1.12	24	80.5	29	2.04	1.79	3.83
September.....	1.12	22	84.1	29	1.99	1.81	3.80
October.....	1.05	29	86.6	31	1.84	1.60	3.44
November.....	1.08	26	90.0	25	1.71	1.55	3.26
December.....	1.09	22	98.2	20	1.62	1.52	3.14
Total and means.....	1.10	240	88.6	254	1.89	1.72	3.61

August 12, when the current program of the Board was completed, daily reports, except Sundays, were made to the Radio Research Aerodrome at Laverton, Victoria, by code telegrams giving the results of preliminary analyses. The traces were forwarded to the Melbourne Office of the Research Board weekly, together with a

copy of the preliminary analyses. The records during September and October were forwarded without analysis.

The ionospheric equipment was in continuous operation. Determinations of layer-heights and critical frequencies were made in accordance with a regular schedule, and preliminary reductions of the observational data were forwarded to Washington at regular intervals. The fixed-frequency recorder was continuously operated from November 1936. Manual-controlled multifrequency runs were carried out according to a regular schedule. Brief reports of the results of these runs, consisting of layer-heights and critical frequencies, were radioed directly to Washington largely through station W3AMS at Washington Grove, Maryland, and more or less frequently through station W6GHD in California. Communication schedules were maintained between the Observatory and Washington through the cooperation of the above stations and with only infrequent interruptions. From June 12, 1936, to May 31, 1937, a total of 255 messages were sent from the Observatory to Washington and 34 messages were received from Washington. Magnetic character of days was reported to Washington weekly by radio and, since March 12, 1937, also the half-day characters for Greenwich days.

The Hale spectrohelioscope was not used during the report-year because of the press of other urgent work and pending the opportunity to train new men. It is expected that, with the receipt of special directions for the use of the spectrohelioscope, the observational program may be resumed soon.

The usual meteorological observations, including sunshine record, nuclei-count, etc., were made daily, and all the self-recording meteorological instruments were kept in continuous operation. Data were supplied monthly to the Commonwealth Weather Bureau in Melbourne as in former years.

The grounds, buildings, and equipment were maintained in order. During November a new Y-shaped air-duct for the conductivity recorders was constructed and put in place in the atmospheric-electric building and a single fan driven by a 110-volt motor replaced the two fans driven by individual 32-volt motors.

Shortage of water at the Observatory still presents an acute problem. Unfortunately a bore 350 feet deep, made in August and September 1936, failed to strike a supply of usable water. It is still necessary to depend on the reduced output from a single well. Two good rains in May 1937, while without effect on the level of the ground-water, indicate, it is hoped, that the approaching rainy season will be normal and that the dry wells will again come into service.

Green continued as Observer-in-Charge. Seaton continued as first assistant and was in charge of the ionospheric work, the heavy program for which he carried in a most satisfactory and commendable manner; he also looked after the radio communication. Culmsee and J. J. Hogan continued their good work as junior observers. T. K. Hogan was appointed junior observer beginning January 1, 1937. Culmsee, who has been at the Observatory for more than five years, is to go to the Huancayo Magnetic Observatory and will leave Watheroo early in July 1937. L. S. Prior, appointed to take Culmsee's place, reported for duty April 21. J. J. Hogan, after four and a half years at the Observatory, has accepted a position with the Commonwealth Meteorological Service and resigned July 15, 1937; Noel G. Chamberlain, appointed to replace him, reported for duty May 12. G. J. Wiltshire (July 1, 1936, to March 27, 1937), John Stobie (March 26 to May 29), and Charles George (since June 4, 1937) have served successively as mechanics.

Continued support and cooperation of the various state and commonwealth departments are gratefully acknowledged. The Department of Trade and Customs of the Commonwealth of Australia aided greatly in importation of equipment. We are again much indebted to Professor A. D. Ross, of the University of Western Australia, for his interest, advice, and assistance.

*Huancayo Magnetic Observatory*—The Observatory is situated in latitude  $12^{\circ} 02' 7''$  south and longitude  $75^{\circ} 20' 4''$  west of Greenwich, in the central valley of the Peruvian Cordillera at an elevation of 3350 m, or 11,000 ft., above sea-level. Eight major pieces of apparatus, listed below, were operated during the year, besides several meteorological instruments.

Two magnetographs—one an Eschenhagen, the other a La Cour rapid-run type—were operated continuously. Control of base-lines was obtained by weekly absolute magnetic observations. Scale-values for horizontal intensity ( $H$ ) and vertical intensity ( $Z$ ) of the La Cour magnetograph were determined electrically once each month. Scale-values for declination ( $D$ ) and  $H$  of the Eschenhagen magnetograph were determined electrically once each week. The  $Z$  scale-value of the Eschenhagen magnetograph was determined electrically three times each week. An additional  $H$ -variometer, of the La Cour type, operating at low sensitivity ( $22.0 \gamma/\text{mm}$ ), was added to the Eschenhagen magnetograph on June 23, 1937. Monthly reports of the more important magnetic disturbances were sent to Washington.

Air-potentials were recorded with standard potential-gradient apparatus. Scale-values were determined each week. Monthly comparisons of potentials measured on open level ground gave reduction- or correction-factors for application to the recorded potentials.

Positive and negative air-conductivities were recorded continuously. Scale-value determinations were made each week. On June 4, 1937, silver-chloride-cell batteries used for operating- and needle-potentials were replaced by B-batteries. The risk of sudden failure of batteries was thereby reduced and measurement of potentials much simplified.

Earth-current potentials were recorded by a Leeds and Northrup apparatus. Two separate systems of north and south, east and west electrodes were used. Owing to the length—some miles—of wire above ground, used in these systems, lightning during the rainy season caused stoppages of the apparatus. Such occasions were of short duration.

Two horizontal-component Wenner-type seismographs and one vertical-component Benioff-type seismograph were in continuous operation. Analyses of important seismic disturbances were made and transmitted by radio to Washington after resumption of radio communications in the spring of 1937.

A Compton cosmic-ray meter recorded cosmic-ray intensities during the year. Some trouble was experienced with one of the operating relays of this apparatus, but this ceased when adjustments were made to the pins of the Landis time-machine. Cosmic-ray "bursts" were frequently noted in the records. Comparison records were obtained for 37 days during May and June 1937 with a portable Millikan-Neher cosmic-ray meter.

Visual observations of the Sun were made daily, whenever conditions of the sky permitted, through the Hale spectrohelioscope. The assigned periods of observation for this Observatory were  $15^{\text{h}} 30^{\text{m}}$  to  $16^{\text{h}} 00^{\text{m}}$  and  $16^{\text{h}} 30^{\text{m}}$  to  $17^{\text{h}} 00^{\text{m}}$  GMT. Coincident disturbances of magnetic, ionospheric, and earth-current records with eruptions on the Sun occurred on November 6 and 27, 1936, and May 25, 1937. These coincidences were specially reported upon for the *Journal of Terrestrial Magnetism and Atmospheric Electricity*. Monthly reports of spectrohelioscopic observations were sent to Washington.

Automatic recording of ionospheric heights was maintained during the year. The program comprised (a) special observation-days during which tests involving a large range of frequencies were carried out, and (b) continuous recording during the remainder of the time on a fixed frequency, namely, 4800 kilocycles. A special five-



day period of test "runs" using a large range of frequencies was carried out from June 6 to 10, inclusive, in connection with the solar eclipse of June 8.

Observations of barometric pressure, maximum and minimum temperatures, relative humidity, rainfall, cloudiness, and wind-direction and velocity, were made daily at 8 a.m., 75° west meridian time. Measurements of the air-content of condensation-nuclei were made daily at the same hour. Continuous records were obtained with barograph, thermograph, hygrograph, anemograph, and sunshine-recorder. Computations and tabulations of magnetic, atmospheric-electric, earth-current, ionospheric, and meteorological studies were kept current, the traces and tabulations being forwarded to Washington monthly. Seismograms and results obtained with the spectrohelioscope were forwarded monthly. Tabulations of barometer pressure, wind-direction, wind-velocity, and sunshine, together with summaries of the meteorological data taken at 8 a.m. daily, were forwarded each month to the Servicio Meteorológico Nacional del Perú.

Preliminary mean values of the magnetic elements for all days of 1936 as deduced from the Eschenhagen magnetograms, referring the elements to the north-seeking end of the needle and reckoning each declination and north inclination as positive, are: declination,  $+7^{\circ} 11.6$ ; horizontal intensity, 0.29609 CGS unit; vertical intensity,  $+0.01150$  CGS unit; and inclination,  $+2^{\circ} 13.5$ . The preliminary values for the

TABLE 4—*Observed annual mean values of reduction-factor, Huancayo Magnetic Observatory, 1925-1936*

Year	Factor	Year	Factor
1925.....	1.04	1932.....	1.08
1926.....	1.05	1932*.....	1.14
1927.....	1.07	1933.....	1.16
1928.....	1.10	1934.....	1.16
1929.....	1.09	1935.....	1.18
1930.....	1.07	1936.....	1.17
1931.....	1.08		

\* Radio masts erected March 1932.

annual changes in the magnetic elements, based on these values and on the *final* values for 1935, are:  $-3.6$  in declination;  $-3$  gammas in horizontal intensity;  $+20$  gammas in vertical intensity; and  $+2.3$  in inclination.

Twelve determinations during the calendar year 1936 of the reduction-factor for potential-gradient records gave a mean value of 1.17 as shown in table 4, which is in good agreement with values determined since 1932, when a change was made in the surroundings.

The preliminary mean values of the potential-gradient and of the atmospheric conductivities are summarized in table 5.

The buildings and general equipment were maintained in first-class order, all necessary repairs being made promptly. In February 1937, 1278 sq. m of land were purchased from the Municipality of Huachac, and in March 1937, 534 sq. m from Doña López. These small areas square out the northern boundary of the site.

There were a number of visitors to the Observatory during the year. Three parties from expeditions to Peru to observe the solar eclipse of June 8, 1937, inspected the work; among these were Dr. J. Stebbins and Dr. S. A. Korff, research associates of the Institution.

O. W. Torreson was Observer-in-Charge through November 1936, and was re-

lieved on December 1, 1936, by F. T. Davies, who had arrived at the end of October. W. E. Scott was first assistant and H. E. Stanton was radio engineer during the entire report-year; T. Astete and A. Macha continued as temporary clerical assistants. Besides these, there were five outdoor employees engaged in maintenance and improvements about the earth-current lines, buildings, and site. The efficiency of the staff is well evidenced by the fact that all compilations of data and all records for June were at the office before the end of July.

Numerous courtesies and much helpful assistance were extended through the cordial attitude of the Ambassador and the Consul-General to Peru of the United

TABLE 5—*Preliminary monthly mean values of atmospheric-electric elements, Huancayo Magnetic Observatory, 1936*

Month	Potential-gradient			Air-conductivity, unit $10^{-4}$ esu				
	Reduction-factor	Value for		Complete days	$\lambda_+$	$\lambda_-$	$\lambda_+ + \lambda_-$	$\lambda_+ / \lambda_-$
		Complete days	In v/m					
January.....	1.16	5	69.9	5	3.60	3.35	6.95	1.07
February.....	1.18	8	63.5	8	3.44	3.36	6.80	1.02
March.....	1.18	10	50.7	10	4.17	4.21	8.38	0.99
April.....	1.17	16	50.2	16	3.57	3.66	7.23	0.98
May.....	1.15	12	42.0	12	4.35	4.60	8.95	0.95
June.....	1.24	22	47.3	22	3.94	4.10	8.04	0.96
July.....	1.19	22	53.0	22	4.20	4.53	8.73	0.93
August.....	1.20	19	48.5	19	3.96	4.19	8.15	0.95
September.....	1.10	14	47.7	14	4.08	4.21	8.29	0.97
October.....	1.13	13	42.0	13	4.91	5.04	9.95	0.97
November.....	1.14	6	53.2	6	3.87	3.94	7.81	0.98
December.....	1.21	9	50.1	9	4.46	4.56	9.02	0.98
Total and means.....	1.17	156	51.5*	156	4.05	4.15	8.19	0.98

\* Mean for 51 days in the wet season, 54.9 volts per meter; for 105 days in the dry season, 48.1 volts per meter.

States and their offices. As in the past, the Observatory maintained cordial relations with the governmental officials and departments of Peru and with the local provincial and municipal authorities.

#### COOPERATION WITH OTHER OBSERVATORIES

*Apia Observatory, Western Samoa*—Cooperation of the Department with the Apia Observatory (latitude  $13^\circ 48'$  south, longitude  $171^\circ 46'$  west) was continued in the fields of atmospheric electricity and terrestrial magnetism. The Observatory also does extensive work in seismology and meteorology.

The program in terrestrial magnetism consisted of absolute measurements of horizontal intensity, declination, and inclination, together with continuous recording by means of autographic instruments of the variations in horizontal intensity, declination, and vertical intensity. Examination in Germany of Tesdorpf magnetometer no. 2025, so long the standard instrument at the Observatory, indicates that it is too old for overhauling. In the meantime CIW magnetometer no. 9, on indefinite loan from the Department of Terrestrial Magnetism, was used for the

absolute observations in horizontal intensity and declination. The Schulze earth-inductor was used for all absolute measurements of inclination. W. C. Parkinson, of the Department of Terrestrial Magnetism, visited the Observatory during June 1937 to compare instruments for the maintenance of control of the corrections on International Magnetic Standards of the absolute instruments. The recording instruments used were a Godhavn balance for variations of vertical intensity and two Eschenhagen variometers for horizontal intensity and declination.

Values of air potential-gradient were recorded during the year at the "Land Station" on the grounds of the Observatory. Following the removal of a *fao* tree in the vicinity of the potential-gradient building, a redetermination of the factor for reducing observed values of potential to volts per meter was made in May 1937. The observation showed no significant change in the reduction-factor. Hence, pending further observations with a convenient regulator by means of which the leak-free and null method of measuring air-potentials can be employed and which has been

TABLE 6—*Meteorological summary, Apia Observatory, 1936*

Month	Pressure	Temp.	Rainfall	Rel. hum. (9 a.m.)	Sunshine	Wind- velocity
	<i>inches</i>	<i>°F</i>	<i>inches</i>	<i>per cent</i>	<i>hours</i>	<i>miles/hr.</i>
January.....	29.719	80.1	14.78	82	164.1	6.1
February.....	29.743	80.3	11.72	81	166.7	5.3
March.....	29.805	79.7	10.92	79	201.7	3.9
April.....	29.805	80.4	8.70	79	197.8	5.6
May.....	29.823	79.8	7.21	79	223.7	5.1
June.....	29.878	78.4	4.10	75	218.9	7.9
July.....	29.882	78.4	3.15	79	234.1	9.6
August.....	29.844	77.2	7.64	75	234.7	8.8
September.....	29.884	78.3	4.72	74	242.9	9.4
October.....	29.857	79.2	12.97	79	185.7	9.5
November.....	29.778	78.7	7.85	77	222.8	5.3
December.....	29.752	79.5	11.38	79	181.7	6.7
Mean or total.....	29.814	79.2	105.14	78	2474.8	6.9

supplied by the Department, the preliminary adopted reduction-factor for 1936 was 1.00 as in previous years. There were 98 zero-days with a mean value of 117 volts per meter. The twelve monthly mean values expressed in volts per meter were: January, 120; February, 116; March, 118; April, 105; May, 98; June, 114; July, 127; August, 120; September, 123; October, 109; November, 119; December, 135.

During the year ended June 30, 1937, 124 seismic disturbances were recorded, many of which were of local origin, but none of them exceeded an intensity of 3 on the Rossi-Forel scale.

The work in meteorology at Apia during 1936-1937 consisted of observations at the surface twice a day and measurements of upper winds from time to time using pilot-balloons. Special flights were made in connection with "International days." The single-theodolite method of following the balloons was used in all ascents, and in flights after nightfall the balloons were followed by means of small lighted lanterns which they carried.

Rainfall reports were received from eighteen local stations in Samoa and one on Swain's Island.

The Observatory also continued to prepare synoptic weather maps of the South Pacific on the basis of reports received by wireless at the Apia Radio Station. Two

maps were constructed daily during the hurricane season and one each day during the dry season. Storm warnings were issued when necessary with the general collective broadcast of weather reports from the Apia Radio Station.

J. Wadsworth, Director, was at the Meteorological Office in Wellington from August 20, 1936, to April 16, 1937; during his absence W. R. Dyer was Acting Director. H. B. Sapsford was on the staff during the report-year. Robert Stanley resigned as clerk after eight and a half years of excellent service.

*Tucson Observatory, United States*—Registration of atmospheric potential-gradients and of positive and negative conductivities, with control-observations and tests, were continued at the Tucson Observatory of the United States Coast and Geodetic Survey by Observer-in-Charge J. Wallace Joyce and assistants in cooperation with the Department.

The observed mean values of reduction-factor for the potential-gradient are shown by table 7.

TABLE 7—*Observed annual mean values of reduction-factor, Tucson Magnetic Observatory, 1929-1936*

Year	Factor*	Year	Factor*
1929.....	1.14(1)	1933.....	1.19(3)
1930.....	1.22(4)	1934.....	1.23(10)
1931.....	1.24(8)	1935.....	1.25(11)
1932.....	1.24(8)	1936.....	1.23(11)

\* The figures in parentheses following values indicate number of determinations on which value depends.

Table 8 summarizes the monthly and annual values of the atmospheric-electric elements.

Registration of earth-currents under a cooperative arrangement with the Mountain States Telephone and Telegraph Company was continued. New electrodes were installed by Dr. Joyce at the Mammoth and Wilcox terminals because of evidence that the insulation of the underground connections to the original electrodes had deteriorated after five years of service. Connection to the Wilcox electrode is now being made by a line leased for that purpose by the Bell Telephone Laboratories, the teletype circuit previously used being required by the home company for its own service. Evaluation of the records emphasizes the marked seasonal variation in type and amplitude of diurnal variation at this station already reported. A decided increase in earth-current activity as the sunspot-maximum is approached is also apparent in the records. Earth-current data for use in studies of correlation with radio fade-outs have been supplied from time to time to the Bell Telephone Laboratories. The records are also being used for the determination of lunar diurnal variation in earth-currents.

The scalings and compilations of hourly values from the atmospheric-electric and earth-current records were kept current at the Observatory by Mrs. G. Dewey, who is employed part-time by the Department.

*Cheltenham Magnetic Observatory, United States*—Cooperation in the development and testing of magnetic instruments at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey was continued by Observer-in-Charge Ludy and assistants of that Observatory and by Johnson and McNish of the Department. The instruments there which served in intercomparison-work for control of the International Magnetic Standards were CIW sine-galvanometer 1



for horizontal intensity and the standard CIW Schulze earth-inductor 48 for inclination, both loaned by the Department.

The electrical standards of the CIW sine-galvanometer 1 were carefully recalibrated with the aid of the National Bureau of Standards. Their performance was found to be excellent, the total change in the constants requiring a correction of only  $-0.3$  gamma to the tables previously prepared. The absolute error due to the drift of the electrical standards during the year was not greater than  $0.1$  gamma, or less than the observational error. It is thus shown that the absolute accuracy of CIW sine-galvanometer 1 depends only upon the constancy of the coil-form, a fact which has already been proved.

The CIW perminvar vertical-intensity induction-variometer was operated satisfactorily throughout the year. The precision cosmic-ray meter installed in 1935 in

TABLE 8—*Preliminary monthly mean values of atmospheric-electric elements, Tucson Magnetic Observatory, 1936*

Month	Potential-gradient			Air-conductivity, unit $10^{-4}$ esu				
	Reduction-factor	Value for		Complete days	$\lambda_+$	$\lambda_-$	$\lambda_+ + \lambda_-$	$\lambda_+ / \lambda_-$
		Complete days	In $v/m$					
January.....	1.21	30	61.7	31	1.97	1.51	3.48	1.30
February.....	1.24	25	62.4	27	2.03	1.56	3.59	1.30
March.....	1.25	28	43.2	30	2.16	1.76	3.92	1.23
April.....	1.24	27	40.3	30	2.14	1.76	3.90	1.22
May.....	1.18	27	39.6	31	2.04	1.77	3.81	1.15
June.....	1.22	25	46.9	30	2.12	1.77	3.89	1.20
July.....	1.31	21	51.1	30	2.12	1.64	3.76	1.29
August.....	1.16	20	52.0	30	2.00	1.70	3.70	1.18
September.....	1.19	24	50.5	27	2.28	1.86	4.14	1.23
October.....	...	28	42.6	23	2.82	2.65	5.47	1.06
November.....	1.21	20	48.6	29	2.40	2.29	4.69	1.05
December.....	1.29	29	59.5	31	2.29	2.09	4.38	1.10
Total and means.....	1.23	304	49.9	349	2.20	1.86	4.06	1.19

cooperation with the Carnegie Institution of Washington operated throughout the report-year under the immediate control of George Hartnell, of the Survey, and the general supervision of Forbush, of the Department.

*College, Alaska*—Good progress was made toward full realization of the ionospheric program in cooperation with the University of Alaska at College, Alaska, much work being done in the laboratory by Professor E. H. Bramhall, of the University. Upon the request of President C. E. Bunnell of the University, Fleming undertook seeing through the press the final report on auroral observations at College during 1930 to 1934. The manuscript by Fuller and Bramhall forms volume III of Miscellaneous Publications of the University.

*Proposed Arctic Observatory, Grinnell Land*—During June 1937, the Department assembled magnetic equipment for the MacGregor Arctic Expedition. This expedition, under the command of C. J. MacGregor, meteorologist of the United States Weather Bureau, left Port Newark, New Jersey, July 1, 1937, for the far north. It was planned to establish a base at Fort Conger (latitude  $81^{\circ} 47'$  north), Lady

Franklin Bay, and to prosecute a magnetic, meteorological, and auroral program from September 1937 to August 1938. An insensitive magnetograph of the La Cour type was supplied to record continuously the magnetic elements. Dip circles with declination-attachments were furnished for obtaining the absolute observations to control the variation-instruments and for observations at field-stations en route and in the vicinity of the base-station. C. J. MacGregor and R. G. Fitzsimmons were trained in the operation of the magnetic equipment and reduction of the observations. Complete directions for the magnetic work were prepared which included plans for the absolute and variation buildings, instructions for mounting and operating the magnetograph and using the dip circles, directions for computation of observations and reduction of magnetograms including specimen sheets, and directions for field-observations. Weekly reports of magnetic storms and magnetic activity will be radioed to the Department.

TABLE 9—*Annual values of the magnetic elements at the Watheroo and Huancayo magnetic observatories as based upon magnetograms for all days*

Year	Declination <i>D</i>	Inclination <i>I</i>	Intensity-components					Local magnetic constant <i>G</i>
			Horizontal <i>H</i>	Total <i>F</i>	North - south <i>X</i>	East-west <i>Y</i>	Vertical <i>Z</i>	
Watheroo Magnetic Observatory								
1935..	3°42'5W	64°21'0S	24672 $\gamma$	56996 $\gamma$	24621 $\gamma$	—1596 $\gamma$	—51380 $\gamma$	35619
1936..	3 37.1	64 21.6	24677	57028	24628	—1557	—51412	35634
Huancayo Magnetic Observatory								
1935..	7 15.2E	2 11.2N	29612	29634	29375	3738	1130	29617
1936..	7 11.6	2 13.5	29609	29631	29376	3708	1150	29615

#### REDUCTION OF MAGNETIC DATA

The Section of Observatory-Work was actively engaged in the reduction of the accumulated magnetic data from the Watheroo and Huancayo observatories. The magnetic observations for the year 1935 from the two observatories were reduced and preliminary reduction for the year 1936 was made. The final mean annual values, based on all days, of the magnetic elements and of the local magnetic constants for the year 1935 and the *preliminary* values for 1936 are given in table 9.

As recorded in last year's report (page 274) the magnet in the Eschenhagen vertical-intensity variometer at Watheroo Observatory was placed 6°5 out of the magnetic prime-vertical in August 1921. That orientation of the magnet prevailed until February 1936, when the magnet was oriented in the magnetic prime-vertical. The manuscript tabulations of the Watheroo magnetic data for 1921 to 1934 were revised to correct for the contribution of variation in declination to the observed variations of horizontal intensity in an orientation other than the prime vertical. The major part of the revision was a recomputation of the diurnal variations in horizontal inten-

sity ( $H$ ), total intensity ( $F$ ), north component ( $X$ ), east component ( $Y$ ), and inclination ( $I$ ). The final revision of the manuscript of Watheroo results for 1919 to 1934 is now complete.

Some time was given to reductions of Polar-Year results obtained at Point Barrow, Alaska. Information and drawings showing in detail the type of construction for magnetic observatories developed by the Department were supplied Dr. A. Ogg, Magnetic-Survey Adviser to the Magnetic Branch of the Trigonometrical Survey of the Union of South Africa.

#### REDUCTION OF ELECTRIC DATA

Wait, Torreson, and Miss Balsam have well in hand the preparation of final tabulations for direct reproduction in publication of the hourly values of the atmospheric-electric elements from records at Huancayo and Watheroo. Following revisions of all calibrations, conversion-tables, and original hourly scalings of electrograms as necessary, a large body of atmospheric-electric data is now being rapidly tabulated in final form. Some fourteen years of data for potential-gradient and positive and negative conductivity are involved in this work. The final tabulations for direct reproduction in publication of the corresponding data at Tucson will be taken up later; the original scalings of electrograms and revision thereof are already completed.

Final reductions of the earth-current data scaled from records obtained at these three observatories were kept current by Rooney.

### OCEANOGRAPHIC WORK

#### REDUCTIONS OF CARNEGIE DATA

*Physical and chemical results*—The final revisions by Fleming, Sverdrup, Ennis, and Revelle of the manuscripts, graphs, and maps giving the oceanographic data secured during the last cruise of the *Carnegie* and of discussions based thereon were completed for the first two volumes of the proposed series "Results of oceanographic and meteorological work obtained on board the *Carnegie*, Cruise VII, 1928–1929, under the command of J. P. Ault." These are volumes I and II on physical and chemical oceanography. Volume I is entitled "Instruments, methods, tables, and graphs of results, and explanation of graphs," by J. A. Fleming, C. C. Ennis, H. W. Graham, E. G. Moberg, Floyd M. Soule, and H. U. Sverdrup; and volume II is entitled "Discussions," by J. A. Fleming, C. C. Ennis, H. W. Graham, E. G. Moberg, C. S. Piggot, R. R. Revelle, Floyd M. Soule, and H. U. Sverdrup.

Final revisions of manuscript prepared and added discussion of the meteorological results were begun in June by W. C. Jacobs at the Scripps Institution of Oceanography under the supervision of Dr. H. U. Sverdrup, research associate. This material will make volume IV of the series. (For notes regarding volumes III and V, see under "Biological results.")

Duvall and Ennis completed an extensive investigation of secular variation from the declinations obtained by the *Galilee* and the *Carnegie* in the Pacific during 1905 to 1929. The high order of accuracy attained is evi-

denced by this discussion, as well as the urgent need for additional reliable data, especially in regions not covered by the *Galilee* and the *Carnegie*.

### BIOLOGICAL RESULTS

Throughout most of the year Graham was occupied at the Hopkins Marine Station, Pacific Grove, California, in a continuation of his studies of the Dinoflagellata of the *Carnegie* plankton-collection. The services of Mrs. N. Bronikovski were employed for the year to assist in the routine examination of the plankton samples and the preliminary sketching of organisms. C. A. Dawson, Brook Cornwall, and Mrs. Abernathy were employed for short periods in the preparation of drawings for publication. The generous co-operation of the Hopkins Marine Station, particularly of W. K. Fisher and T. Skogsberg, was extended as in previous years. During the latter part of June, Graham removed to Palo Alto, where, through the cooperation of Dr. Spoehr, of the Division of Plant Biology, headquarters were established in the laboratories of that Division and intensive work started on the library research necessitated by the preparation of the dinoflagellate report.

The routine examination of the plankton-samples was completed for the south and north Pacific except for the last 20 stations, between the Hawaiian and Samoan Islands. The examination of samples and sketching of contained organisms was accomplished for 354 samples; over 2000 working drawings were executed. The number of mounted specimens now totals about 2500; the collection of camera-lucida drawings now contains over 7000 sketches; the number of species recorded to date is approximately 350.

In a continuation of the study of the thecal morphology and interrelationships of the members of the Peridinioidæ a detailed analysis of the following forms was made: *Goniaulax pacific*, *G. fusiformis*, *Spiraulax kofoidi*, *Goniodoma polyedricum*, *Ceratium pavillardii*, *Peridinium truncatum*, *P. crassipes*. Finished drawings and descriptions were completed for the following other forms: *Peridinium grande*, *P. elegans*, *P. Bronikovskiyi*, *P. egenum*, *P. triangulum*, *P. fatulipes*, *P. alatiferum*.

The distributional studies which are just being started promise to contribute a great deal to our knowledge of the interrelationships of biological and physical conditions of the oceans. The distribution of the species of *Ceratocorys*, for instance, has been plotted, and one species in particular, *C. horrida*, has proved to be a good indicator of tropical water-masses. Its distributional limits are very sharply defined where the waters of the Kuro Siwo meet the Oya Siwo; at the area of influence of the California upwelling; at the borders of the Humboldt Current; and in that region of the Gulf Stream where a decided cooling has taken place. It was found that it did not occur in water with a temperature less than 19° C. Many more examples of such correlations doubtless will appear in the rest of the material. Other tropical forms less sensitive to cold water, such as *Ceratium hexagonum*, indicate intrusions of water of tropical origin into colder regions. Boreal species do the converse. No other expedition has as extensive material as that of the *Carnegie*, which offers an unusual opportunity for such studies.

Dr. A. S. Campbell, of Berkeley, completed his work on the tintinnoids in



the *Carnegie* collections and has submitted an extensive memoir with illustrations discussing the results of his investigation under the title "The oceanic Tintinnoida."

### MISCELLANEOUS

Peters continued until September as consultant to the British Admiralty in London in connection with the designs for the nonmagnetic vessel *Research* and her instrumental equipment. After attending the Assembly of the International Union of Geodesy and Geophysics at Edinburgh in September, he returned to the United States in October. The CIW-type magnetometer-inductor ordered by the British Admiralty for the *Research* was received from the manufacturers in September. After several alterations following tests, the constants and corrections on International Magnetic Standards were determined and the instrument was forwarded to England. The tabulations of constants and instructions for its use were sent early in 1937 to the Astronomer Royal.

Fleming prepared a report entitled "Magnetic survey of the oceans" at the request of Dr. T. Wayland Vaughan for use in his book on "International aspects of oceanography," to be published by the National Research Council.

Graham attended the meetings of the Western Society of Naturalists at Los Angeles, December 29 to 31, 1936. He took part in the seminar of the Hopkins Marine Station and presented two papers, namely, "Metabolism of the sea" in December and "Pacific equatorial currents" in January.

### INSTRUMENT-SHOP

As in past years, the various investigators have found their researches greatly advanced by the skillful collaboration of the men in the shop. Steiner, in charge of the instrument-shop, was assisted by Lorz, Haase, A. Smith, Huff, Malvin, and Mitchell. The major projects were the equipment for ionospheric research, the electromagnetic measuring device, the experimental building for ionospheric research, the CIW exhibit, and improvements to the main building. Considerable time was required for putting instruments, after return from the field, in good order and adjustment and for overhauling several of them.

The first shop experimental model of the ionospheric apparatus for automatic multifrequency pulse-transmission was completed and was tested at Kensington. A second unit, with modifications based on these tests, was constructed and demonstrated at the CIW exhibit. At the end of the report-year the complete multifrequency unit was operating at Kensington for final test before shipment to Huancayo in September 1937. The similar apparatus to be used at Watheroo is already under way.

After the design of the mounting of the pyrex cylinder for the electromagnetic magnetometer was decided upon, the grinding, polishing, and necessary drilling were completed, as well as the grinding of the double thread of 1-mm pitch as guides for lap. This completes the work on the pyrex cylinder in the shop, and it is now ready for final lapping in the constant-temperature room. A constant-temperature control-unit was constructed for use while the final work is being done on the cylinder in the constant-

temperature room. The casting for the special micrometer yoke for measuring the primary coil was obtained and aging treatment was applied. A cooling chamber was constructed in which the coil-form may be passed through cooling cycles to remove hysteresis.

Four potential-regulator units were built primarily for use when making potential-gradient standardization measurements using the leak-free and null method.

Miscellaneous items included the following: demonstrating model for Carnegie Institution exhibit showing method of exploring the ionosphere, which was later altered for exhibit at the New York Museum of Science and Industry; packing of equipment for observatories and for cooperating organizations; overhauling, repairing, and adjusting instruments for use by the MacGregor Arctic Expedition; upkeep, maintenance, and improvement of buildings, building equipment, and grounds. The facilities of the shop were made available during September and October 1936 to J. A. Kuhn to permit him to construct a CIW-type ion-counter (under the supervision of Wait) for the United States Department of Agriculture.

### MISCELLANEOUS ACTIVITIES

*Communications to scientific organizations and universities*—Bartels lectured at the University of Berlin on (a) physics of the highest layers of the atmosphere, (b) variability in geophysics and meteorology, and (c) gravity and seismology. He addressed two meetings at Magdeburg and Eberswalde on sunspots and their terrestrial effects.

Members of the staff took active part in meetings of American scientific societies through papers and discussions as indicated elsewhere in this report. A number of papers were presented in April 1937 at the General Assembly and at the meetings of the several sections of the American Geophysical Union. Fleming and Capello prepared for publication the *Transactions* of the Eighteenth Annual Meeting of that Union (two volumes containing 664 pages). Accounts of the Edinburgh Meeting of the International Union of Geodesy and Geophysics were presented by Fleming and Berkner before the Philosophical Society of Washington.

*Conferences and congresses*—Fleming, Peters, Berkner, Harradon, and Bartels attended the Sixth General Assembly of the International Union of Geodesy and Geophysics at Edinburgh, Scotland, September 16 to 26, 1936. The Department staff contributed extensively to the papers presented, especially before the Association of Terrestrial Magnetism and Electricity (see list of publications elsewhere showing these papers published in the *Transactions* of the Edinburgh meeting of that Association). Fleming was reelected for a three-year term as President of the International Association of Terrestrial Magnetism and Electricity, and Berkner was elected Secretary of a Joint Committee of that Association and of the International Scientific Radio Union. Preceding and following the meetings at Edinburgh, Fleming, Berkner, and Harradon made numerous contacts with persons interested in the activities of the Department at London (including the Slough Station of the National Physical Laboratory and the Chelmsford Laboratory of the

Marconi Company) and Cambridge in England, at Bergen and Oslo in Norway, at Copenhagen in Denmark, at Berlin, Munich, and Kokel in Germany, and at Paris in France. These men took active part also in the Conference on Atmospheric Ozone held at Oxford, England, September 9 to 11, 1936. As a member of the Executive Committee of the International Council of Scientific Unions, Fleming prepared a statement for the July 1937 meeting of that Committee in Paris entitled "On the researches in terrestrial magnetism and electricity which are contributing to the advancement of scientific knowledge."

Members of the Department took active part in the Cycle Conference which was held at the Carnegie Institution of Washington under the direction of Dr. A. E. Douglass April 23 to 25; Fleming, Berkner, and McNish made some remarks with particular reference to the possibilities of the cyclograph of Dr. Douglass in the work of the Department.

McNish presented a paper entitled "Terrestrial-magnetic variations and the ionosphere" in the Symposium on Astrophysical Problems of the Ionosphere held under the auspices of the American Association for the Advancement of Science at Denver, June 25, 1937.

*Exhibits*—At the annual exhibit of the Institution held in December, the Department's contribution related to the exploration of the Earth's high atmosphere with radio waves. It included an actual equipment showing how the electrical state of the upper atmosphere throughout its extent is continuously and automatically recorded. Upon the completion of the annual exhibit at the Institution, the Department's exhibit was especially prepared and sent for a three months' display at the Museum of Science and Industry in New York. The exhibit to illustrate field and observatory instruments, methods, and results in the polar regions mentioned in last year's report was continued, upon request, for use through November 1937 at the Pan American Exhibit in Dallas.

The air-conductivity apparatus and results obtained in the stratosphere were exhibited during December at the Atlantic City meeting of the American Association for the Advancement of Science in connection with the exhibit of the gondola of the *Explorer II* by the National Geographic Society.

*Staff-meetings and colloquia*—Afternoon biweekly staff-meetings were held during November 1936 to April 1937, there being presented at each, by invited guests and staff-members, some topic pertaining to research in the Department's fields. A weekly evening seminar in terrestrial magnetism was held in the library of the Department from October 19, 1936, to March 1937; this seminar, attended by members of the staff, related to the fundamentals of potential theory and the development and application of spherical harmonics to the distribution of the Earth's field and its physical aspects and origin. Members of the staff took part in the weekly morning staff-meetings of the National Bureau of Standards and the weekly evening meetings of the Washington Physics Colloquium.

*Library*—Outstanding works of interest relating to terrestrial magnetism and electricity and other fields of interest to investigations in progress at the Department were added to the library. There were 603 accessioned ad-



ditions during the report-year, bringing the total number of accessioned books and pamphlets to 24,145. As in the past, all important articles bearing on the Department's fields of research which appeared in current scientific journals, of which about 100 are regularly received, were carded, classified, and filed in the library-index. Taking account of these references and the books available, our index becomes each year more valuable as a reference-tool.

Harradon, as librarian with the assistance of Dove, continued to take part in editing manuscripts as also contributions to the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, particularly those in foreign languages. The annotated lists of recent publications, abstracts, and notes were prepared for the various issues of the *Journal*. Harradon translated articles and documents and letters pertaining to international scientific papers and congresses.

A list of papers by the members of the Department's staff as compiled by the librarian for 1936 shows that the total number of such publications on December 31, 1936, was 1588. Reprints of contributions were distributed to institutions and individuals on the regular mailing-list. The service of the International Exchange Bureau of the Smithsonian Institution was utilized, as on previous occasions, in the case of foreign countries, thus effecting considerable economy in postal charges. The stock of reprints was rearranged and so filed by Dove as greatly to facilitate distribution.

Research workers and students from various institutions and governmental bureaus were extended the privilege of utilizing the material in the library. Loans of volumes were made to libraries in Washington, D. C., and Cambridge, Massachusetts. The cordial and reciprocal relations with other libraries, particularly with the Library of Congress, were maintained.

*Office administration*—The great amount of bookkeeping, financial statements, audits of accounts, correspondence, instructions, reports, and manuscripts concerned in the functioning of the Department and its wide-spread outside activities was efficiently handled by M. B. Smith, chief clerk, with the assistance of Moats and Singer. Much of the detail in connection with preparations for the construction of the Atomic-Physics Observatory fell upon the Chief Clerk. As secretary and property clerk, Capello shared responsibility with the Chief Clerk for the large amount of shipping to and from our observatories; he also prepared final copy of many manuscripts. Hendrix did an unusually large number of drawings to illustrate papers, to show instrumental and building details, and for exhibits.

*Bibliography*—A list of the published contributions of investigators and research associates from July 1, 1936 to June 30, 1937 is given in the report of the Institution's Office of Publications.





## ANTHROPOLOGY

**Aberle, Sophie D.**, United Pueblos Agency, Albuquerque, New Mexico.  
*Studies of the growth and development of Pueblo Indian children.* (For previous report see Year Book No. 34.)

These studies, which were begun by Dr. Aberle a few years ago, have been continued with aid from the Carnegie Corporation of New York, and more recently other studies have been added in cooperation with the research program of the Carnegie Institution of Washington and the activities of the U. S. Office of Indian Affairs and other agencies.

### POPULATION AND VITAL STATISTICS

*Census of the Pueblo area*—An enumeration of the population in 16 of the pueblos was initiated and completed in the course of the year. The field work was carried out by two trained employees of the Indian Service, with the assistance of interpreters delegated by the governor of each pueblo. The task included not only a careful count of all pueblo members, both resident and nonresident, but also the collection of the customary descriptive data, as age, sex, degree of blood, marital status, family relationship, and residence. The information collected in the field was checked by the interpreters and with previous census rolls and birth and death certificates. The census roll for each pueblo was then submitted to the governor and council in full meeting. As each governing body signed and certified the roll as correct only after a careful reading and thorough correction, the rolls are now recognized as the official census of each village.

*Native registrars*—To keep the census rolls up to date, a responsible member of each pueblo was appointed by the governor and council to serve as registrar. Registrars are supplied with suitable forms and receive a fee from the Agency for each report of a birth, death, or marriage. It is hoped that this acceptance of responsibility by the local governing bodies will result in fuller and more complete reporting than was possible before.

*Population register*—The foundations of a population register have been established to provide in permanent form a continuous record of the life history of each Pueblo Indian. A record card, planned in consultation with statisticians of the Office of Indian Affairs and the Technical Cooperation to the Bureau of Indian Affairs, was further elaborated with the Yale University Department of Public Health. A beginning has been made in transferring to these cards the data contained in the certified census rolls, and a full-time clerk has been assigned the task of keeping them up to date through reports of births, deaths, and marriages. As far as can be learned, this is the first time that a serious attempt has been made to establish in the United States a population register at all comparable with those so successfully operating in Scandinavian countries.

*Vital history of San Juan Parish*—During the spring and summer an intensive analysis was made of the records of San Juan Parish under the direction of Dr. John H. Watkins, of the Department of Public Health, Yale University. The basic material, collected during the past few years, con-

sists of the baptismal, funeral, and marriage registers kept by the local Catholic church since 1726 and all population figures obtainable in the Spanish Archives, for the eighteenth and nineteenth centuries, and in the publications of the Bureau of the Census and the Bureau of Indian Affairs, for the American period.

The material was coded in such fashion as to yield data concerning both the Indian pueblo in which the church is located and the surrounding area, which is largely of Spanish origin.

The primary procedures were the construction of mortality and natality curves with adjustments appropriate to various minor discrepancies characteristic of such data, and the construction of a population curve covering a period of more than two hundred years. With the population curve as a basis, mortality and natality rates were computed for different periods. Particularly full population data for the year 1790 permitted the construction of a life expectancy table for the end of the eighteenth century. The mortality data were further analyzed for epidemics, their cyclic occurrence, and the character of each. Of special interest is the smallpox epidemic of 1781, during which the gross mortality in the parish rose from a yearly average of 20 deaths to over 200 in one month. Other significant yields have been obtained through the determination of the population composition and changes in composition, and of sex and plurality ratios.

For the purpose of the study, the original transcripts of the birth, death, and marriage records were transferred to cards and cross-references established among the different items concerning the individual. These files, arranged in alphabetical order, form an excellent basis for future genealogical studies of this particular area in New Mexico.

*Vital statistics of the Pueblo population*—An immediately useful extension of the San Juan study is the analyses of the modern vital data for the entire Pueblo population. An analysis for age and sex composition has already been carried out on the 1936 certified census material with the assistance of the Technical Cooperation to the Bureau of Indian Affairs. Mortality and natality rates, over a period of time long enough to be significant, will be computed from material in the files of the United Pueblos Agency.

#### DIMENSIONAL GROWTH AND DEVELOPMENT

*Field work*—The detailed anthropometric study was continued with a fifth annual series of more than 50 measurements, including observations on breast and nipple size, on the selected group of 200 Indian children, now ten to fifteen years of age.

*Statistical analysis of heights and weights*—This work was begun in July at the University of Minnesota and continued through December in consultation with Dr. Edith Boyd and Dr. Richard E. Scammon, of the Department of Anatomy. The study was divided into two parts: (1) a description in terms of height and weight of the pre-adult population as represented by day school children, and (2) a determination of the effect of supplementary feeding of halibut liver oil upon the growth in height and weight of a fraction of the population.

1. The height and weight material consisted of 3000 measurements of each taken in 1931-1934 on all available Pueblo and Hopi day school children between the ages of six and sixteen years inclusive. Curves of growth in height and weight were constructed for the whole population and for the population of each pueblo and the results tested for significant differences. With a view to the use of the means as a standard in part 2, the computations were carried out for as small age periods as possible in order to reduce to a minimum variation attributable to progression.

2. The material consisted of four annual series of measurements of height and weight taken on 200 of the day school children, half of whom had been given supplementary feedings of halibut liver oil during the three intervening school years. The deviations in height and weight for each individual from the mean height and weight of his fellows of the same age were computed and the mean deviations of these two groups, halibut liver oil and control, tested for significant differences. No significant difference was found between the two groups.

#### PUEBLO ORGANIZATION AND ECONOMY

*Political organization of the Pueblo villages*—As a preliminary to organization of the pueblos under the Wheeler-Howard Act and to the formulation of constitutions, informal inquiries into the present internal organization of each village gave the superintendent an opportunity to collect information on Pueblo administrative and legal procedures. Such information has been accumulating slowly throughout the past year. As previously explained, though this information is confidential in nature and cannot be published in detail, it is valuable in providing fundamental concepts by which to interpret other data.

*Economic status of Santa Clara Pueblo*—An analysis of the social and economic factors affecting the Indians of Santa Clara Pueblo has been made by Mr. A. L. Walker, of the Indian Service. Though this study was directed primarily toward administrative action, it has brought together some available material related to the economy of the pueblo and suggested a pattern for similar studies in other pueblos.

*History of Pueblo lands*—Maps showing the various areas owned by each pueblo have been completed for all but the two pueblos of Taos and Zuni by Mr. Guy Harrington, cadastral engineer, Department of the Interior. In addition to extent, the maps show the date of acquisition of each area and the method of acquisition, as executive order, congressional act, or purchase.

*Individual agricultural landholdings*—Last year maps of individual agricultural landholdings of a number of pueblos had been completed by the Soil Conservation Service. In the past year two more have been completed. The work involved in making a single map may be realized when it is considered, taking Taos as an example, that 1400 to 1500 separate tracts must be claimed and staked out by their owners, surveyed and mapped, and their acreages computed. It is then possible to determine from the maps the number of landed and landless Indians in each village, the quantitative distribution of land among landholders, the size and the consolidation or



scattering of each individual's holdings. While the work was initiated primarily to discover which Indians were entitled to additional lands recently purchased with compensation money, it is of further value in showing the economic status of family groups in the pueblos.

*Agriculture in former times*—The elders of three tribes have given information to engineers of the Indian Service on the location of old cultivated lands and irrigation ditches no longer in use. This has been checked in the field and reconstructions have been made of areas under cultivation and lines of irrigation systems from the remaining traces of ditches, borders, and furrows.

## ARCHÆOLOGY

**Caso, Alfonso**, Mexico City, Mexico. *Continuation of archæological and historical studies in the region of Oaxaca, Mexico.* (For previous report see Year Book No. 35.)

During the past year, which witnessed the sixth season of work at Monte Alban under the direction of Dr. Caso, these studies were aided by grants from the Carnegie Institution of Washington, representing in part funds made available for the purpose by the Carnegie Corporation of New York. This program has also been undertaken through cooperation of the Pan American Institute of Geography and History.

The work was carried on during the late winter and the spring of 1937. The first weeks of the season were devoted to explorations in a part of the Mixtec area in the state of Oaxaca to which attention had not previously been given by archæologists, and whose antiquities were therefore known only through such few specimens as had reached the National Museum as the result of casual finds. The town of Nochixtlán was made the center of operations for investigation of sites at Pueblo Viejo, Tinducarrada, Yucuita, and Yucuñudahui.

The ruins at Yucuñudahui proved of greatest interest and importance. Situated on a ridge, they consisted of numerous mounds, including the remains of a ceremonial ball court and a temple identified by Dr. Caso as a shrine of the Rain God. Limited excavation permitted recovery of architectural data and of ceramic materials. On an outlying spur of the same ridge there was discovered the elaborate tomb of a priest or ruler. Sunk in the ground, its antechamber was reached by a short flight of descending stone steps. Both antechamber and main chamber were roofed with wooden beams which, though broken down by the weight of the ancient tumulus, were still in excellent preservation. At the entrance was a stone slab, bearing parts of an elaborate ritualistic painting, and inset in the walls of the main chamber were hieroglyphically sculptured slabs. The pottery vessels accompanying the numerous skeletons of the tomb proved to resemble wares of the Third Period of Monte Alban.

The principal excavations of the season were conducted at the great ruins of Monte Alban, where in previous years Dr. Caso has made such remarkable discoveries.

From the Sunken Court was recovered a series of ceremonial caches, containing carved jades. Finds of outstanding interest and scientific value were made in three tombs, numbered 103, 104, 105. From the former came many anthropomorphic vessels of the Third Period, including a fine effigy of the god Xipe Totec. Tomb 104 was entered through an elaborate portal. In a niche over the doorway was the figure of a god in black pottery, and the door slab bore sculptured glyphs which add greatly to the hitherto rather limited corpus of Zapotecan epigraphic material. On the walls of the mortuary chamber were paintings, parts of which were in excellent preservation, depicting richly caparisoned figures.

At the opening of this tomb was present General Lázaro Cárdenas, President of Mexico, who assisted in removal of the many effigy vases accompanying the burial. Tomb 105, though less spectacular than Tomb 104, has paintings which are finer although less visible. A jade mosaic was found in the fill that covered the patio of this tomb.

Although the pottery and other specimens have, of course, not as yet been subjected to intensive final study, it is already evident that Third Period Monte Alban ceramics are related to those of Teotihuacan. The linkage, mentioned above, of Mixtec wares from Yucuñudahui with Monte Alban III further extends the correlation of Mexican ceramic groups which Dr. Caso's researches are doing so much to render precise, and which is so necessary for reconstruction of the history of the higher New World civilizations.

A most significant conclusion reached by Dr. Caso as a result of his study of the Monte Alban tomb paintings is that none of the ancient codices hitherto believed to be of Zapotecan origin can rightly be attributed to that culture, because the hieroglyphs from the tombs are so radically different from those of all such codices.

## ASTRONOMY

**Committee on Meridian Astrometry, Benjamin Boss, Chairman, Dudley Observatory, Albany, New York.**

Activities of the Department of Meridian Astrometry of the Institution terminated in December 1936, but provision was made through appointment of a special Committee on Meridian Astrometry, with Mr. Boss as chairman, for responsibility for completion of the *General catalogue of 33342 stars*. The material comprising the five volumes of this catalogue has been brought together, and it is expected that the entire work will be printed and available for distribution by the end of 1937.

The Committee on Meridian Astrometry has also been asked to formulate suggestions for future investigations in the field of meridian astrometry, to be considered in the light of special tasks based upon study of materials in the *General catalogue of 33342 stars*.



## BIOLOGY

Castle, W. E., University of California, Berkeley, California. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3-35.)

In October 1936, the location of the experimental studies was changed from the Bussey Institution of Harvard University to the Division of Genetics of the University of California in Berkeley, whose officials have done everything possible to facilitate the work and to whom grateful thanks are hereby expressed. An excellent room for mouse and rat colonies was fitted up in the Veterinary Science Laboratory in Strawberry Canyon, and a detached rabbit house with needed equipment was constructed alongside of the poultry houses.

The first task was to secure inbred strains of mice which could be relied on to be uniform in genetic constitution, for use in a further study of the influence of particular genes on body size. In securing such strains valuable assistance was received from former associates at the Bussey Institution, in particular from Dr. L. C. Strong, of the Yale Medical School, Dr. E. C. MacDowell, of the Department of Genetics of the Carnegie Institution, and from Dr. C. C. Little, Director of the Roscoe B. Jackson Memorial Laboratory.

In the intervening months a large population has been raised consisting of  $F_1$  and backcross mice which, when they are fully grown (about December 1937), should give us an answer to the question, Is the albino mutation one which influences the rate of growth of the body?

Other mouse crosses which are being made are designed to show whether the mutant genes, leaden, pink eye<sub>2</sub> of Roberts, and some others have any influence on the rate of growth of the body.

In a previous report it was stated that the mutations brown and blue in the mouse act as accelerators of body growth. Since mutations similar to these occur also in the Norway rat and in the rabbit, experiments have been started to discover whether these mutations have similar effects on growth in those species also. The initial crosses have been made in the case of the rat with stock supplied by a former associate, Dr. P. W. Gregory, now of the College of Agriculture at Davis, California, and by Dr. Helen Dean King, of The Wistar Institute, with whom the writer has been cooperating in the study of linkage in the rat. The desired foundation stocks of rabbits have been in part supplied by a former associate, Dr. P. B. Sawin, of Brown University, who has kindly carried along in Providence certain of the stocks originally synthesized at the Bussey Institution, which are essential to the present experiments. Other stocks have been obtained by purchase or gift from rabbit breeders. It has required some months to build up the foundation stocks to an adequate size and make the initial crosses. We are now ready to go ahead with the critical experiments.

In cooperation with Dr. Helen Dean King, of The Wistar Institute, a further study has been made of genetic linkage in the rat. A waltzing mutation (*w*) discovered by Dr. King in an inbred strain of wild gray rats has been shown to be loosely linked with albinism (*c*), thus demonstrating the

existence in the albino chromosome of the genetic loci for four mutant genes, a maximum number for a mammal up to the present time. The order of the four mutant genes is apparently *crpw*. The crossover percentage between the gene for albinism (*c*) and the gene for waltzing (*w*), by two different methods of calculation, is found to be  $44.7 \pm 0.7$ , and  $45.8 \pm 0.7$ , based on a total backcross population of 2139 individuals. These are small but consistently significant deviations from 50 per cent, which would indicate free assortment.

**Conger, Paul**, Washington, District of Columbia. *Continuation of investigations and preparation for publication of results of studies on Diatomaceæ.* (For previous reports see Year Books Nos. 18–35.)

The early half of the summer was again spent at the Chesapeake Biological Laboratory in field work and investigation, and during this period a special course on diatoms, inaugurated several summers ago, was given to six graduate students working for higher degrees in botany or oceanography. The increasing demand for this course is indicative of a growing interest in the field, specialized though it be, and the time devoted to it proves no more than adequate to survey briefly the diatom group and the many important aspects of the subject. During the stay at the laboratory much fine material was obtained from the vicinity for continuation, during the year, of studies on the distribution and ecology of diatoms of the Chesapeake Bay region.

Following this work, six weeks were again spent among the northern Wisconsin lakes collecting and studying the diatoms of the lakes, a continuation of work of the previous summer. Over two hundred samples were obtained from 72 lakes, making a total of somewhat over 100 lakes visited during the past two summers. Material was obtained for study of certain special problems, for which this region is especially well adapted.

Upon return from Wisconsin it was learned that a very heavy outbreak of a certain plankton diatom in the Potomac River was causing considerable trouble and additional cost to the city water-supply system, and cooperation was given the engineers dealing with the problem. The occurrence was similar to that of two years ago but much more extensive, as well as of longer duration and consequent detriment. Some of the conditions involved in the unusually abundant production of this diatom and its nature were studied, and splendid material was obtained for further studies upon its nature and effects during the winter. Studies in the laboratory substantiated the practical conclusions of the water-supply engineers with regard to desirability of making some alterations in their methods for quantitative determination of the flora of such waters. A descriptive paper on the whole matter of these occurrences and their various important aspects is in course of preparation.

During the fall an illustrated article was prepared for inclusion in the next Smithsonian Annual Report on "The significance of shell structure in diatoms." This unique and important feature of diatom biology and economics has not heretofore, to the writer's knowledge, been presented from this viewpoint. Here too, it is believed, are shown for the first time actual photographs of the double shell wall structure, which previously has been

possible of depiction only by interpretative drawings. Also, the importance and nature of the shell structure is brought out in the plates in several new ways, which should serve to elucidate and emphasize this feature. The photographs of the intricate shell structure are made possible by a new process which will be described in a later paper.

Suggestions and help were given during the year to several chemists and manufacturing concerns with regard to the physical nature of various diatomite materials, and adaptation to their several specific needs. Some help was also given with regard to problems arising in the processing of certain diatomites. Many requests were answered as usual for information regarding diatoms and materials.

During the spring cooperation was given in the preparation and presentation of an exhibit at the Academy of Natural Sciences of Philadelphia in connection with the International Symposium on Early Man held at that institution for four days in March, and these meetings were attended. In the exhibit mentioned emphasis was placed upon the special application of diatoms and plant pollens in stratigraphic determinations in areas associated with finds of early human remains and artifacts.

An illustrated talk was given before the Washington Botanical Society at the Cosmos Club, entitled "The diatom, an economic plant," in which were discussed the various phases of the economic importance of diatoms and the underlying biological basis for their importance in these several respects, the full significance of these matters being rather meagerly appreciated by men otherwise well informed in botanical knowledge.

A talk was also given before the spring conference of the Division of Animal Biology of the Carnegie Institution at Baltimore, concerning the subject "Significant problems and materials for diatom research, and their interpretation."

An intensive study was made and report prepared for Dr. Hellmut de Terra, Research Associate of the Carnegie Institution of Washington, at the Philadelphia Academy of Natural Sciences on about twenty samples collected by him in Kashmir, India, and a few from Nebraska and Colorado Pleistocene deposits, bearing also other fossil remains.

An extensive report on the collections made by Sir Douglass Mawson on his Australasian Antarctic Expedition and also by the Sir Ernest Shackleton Expedition to the Antarctic, prepared by Dr. Mann and submitted to the Australian Government several years before his death, has been published during the past year. Delay in publication was due to lack of funds at the time. This represents the last finished work of Dr. Mann and is a very important contribution in that it covers large collections from an area otherwise little studied. For exact citation see bibliography.

**Dice, Lee R.**, University of Michigan, Ann Arbor, Michigan. *Studies of the ecology and genetics of North American mammals.* (For previous reports see Year Books Nos. 31-35.)

Several years ago the writer reported the indication of a geographic trend in the body and skeletal measurements of the prairie deer mouse, *Peromyscus*



*maniculatus bairdii*. A stock of mice from North Dakota had the largest measurements of the three stocks for which figures were at hand, a Michigan stock had the smallest measurements, while an Iowa stock was intermediate. There are now available four additional stocks of *bairdii*, and the indication of a geographic trend in size in this race is shown to be erroneous. There is much local variation in size and body proportions and also in pelage color in these mice, but no certain trend for any character in any geographic direction is shown by the stocks of this subspecies.

To the mouse colony in the Laboratory of Vertebrate Genetics, University of Michigan, new breeding stocks of *Peromyscus* have been added during the year, of the forms *attwateri*, *austerus*, *bairdii*, *blandus*, *hollisteri*, *noveboracensis*, *oreas*, *rubidus*, and *sonoriensis*, coming from the states of Idaho, Massachusetts, Michigan, Oklahoma, Oregon, Texas, and Washington. Laboratory-reared mice prepared as specimens during the year number 2084.

During August 1936 a hasty trip was made through eastern Canada in order to trace the boundaries of the biotic provinces of this part of eastern North America. The boundary between the Hudsonian and Canadian provinces is quite well marked, except where mountains break the continuity of the climatic zones. However, considerable difficulty in discriminating between the so-called Canadian and Alleghanian faunas was encountered. The facts of biotic distribution would perhaps be better expressed by combining these two faunas into a single biotic province, characterized by the occurrence, on different soils, of hardwood forest, upland conifer forest, and bog forest.

A catalogue of the mammals of the state of Sonora, Mexico, has been prepared by W. H. Burt, based in part on collections made on expeditions sponsored by the Carnegie Institution of Washington. According to the conclusions of Dr. Burt, four biotic provinces are represented in Sonora.

Linkage tests between the various mutant characters of the deer mouse, *Peromyscus maniculatus*, have been continued by Frank H. Clark. It has been demonstrated that buff is not linked with yellow or hairless. Yellow segregates independently from dilute, albinism, and hairless. Hairless is not linked with albinism. Further data have been obtained on the amount of crossing-over between the linked characters pink eye (formerly called pallid) and albinism. Crossing-over between these characters in  $F_1$  females is  $19.94 \pm 1.44$  per cent, while in  $F_1$  males it is only  $13.16 \pm 2.70$ . The difference in crossover percentage is  $6.78 \pm 3.06$ . This difference is 2.21 times its probable error and, while not significant statistically, indicates that in the deer mouse, as in the house mouse and Norway rat, there may be less crossing-over in males than in females. In the cactus mouse, *Peromyscus eremicus*, pectoral buff spotting behaves as a simple recessive character. Postjuvenile nude, a new type of hairlessness, is caused by faulty keratinization of the hairs of the postjuvenile coat which causes them to break off at or beneath the surface of the skin. Nude is a simple recessive character and arose in a stock of *Peromyscus maniculatus osgoodi* from Bear Lake, Utah.

A statistical study of size in mature mice of the genus *Peromyscus* has been completed by Dr. Clark. Correlations and ratios between certain body and skull measurements were calculated for 42 stocks of mice representing



3 species and 10 subspecies. No consistent differences between species or subspecies occur in respect to the degree of association between the several dimensions of the body or skeleton as determined by simple correlation coefficients. The ratios, on the contrary, reveal many significant differences in body proportions even between stocks of mice of the same subspecies. Species differ more than subspecies in body proportions, owing mainly to differences in size of the extremities, especially the tail and the ear length. There are fewer differences among these mice in relative size of the parts of the main body trunk and skull. Both the correlations and ratios indicate that general body size in *Peromyscus* is determined largely by general growth factors or growth gradients, while tail, foot, and ear length are influenced to a large extent by specific growth factors.

Studies of the mode of inheritance of waltzing and epilepsy in mice of the genus *Peromyscus* have been continued by Margaret Liebe. In a stock of deer mice from the Palouse River, Washington, epilepsy and waltzing are closely combined and are recessive in inheritance. There is considerable variation in the type of behavior response of individual animals and it seems probable that waltzing and epilepsy are only different types of response based on the same inherited defect. However, it is probable that inherited modifying factors also play a part. The animals lose their ability to hear at varying ages, and their defective type of behavior ceases at approximately the time that they become deaf.

**Morgan, T. H., C. B. Bridges, and Jack Schultz**, California Institute of Technology, Pasadena, California. *Constitution of the germinal material in relation to heredity*. (For previous reports see Year Books Nos. 15-35.)

The revision of the map of the salivary X-chromosome has been completed by Bridges. The new map is 414 microns long, as compared with 220  $\mu$  for the last published chromosome map. The difference in length is due to the selection of especially large chromosomes which are also stretched to greater degree. Both the larger size and the greater stretch enable more "bands" to be resolved into "lines." The number of "lines" or visually distinct transverse markings represented on the new map is 1024, as compared with 725 on the former map. The relative intensity, spacing, morphology, and other features of the lines are much more accurately represented, from averaging the 3 to 7 best drawings for each of the twenty divisions of the map. The numbering of the lines, including even the faintest, is a feature of great convenience in the new map since it makes possible precise and unambiguous references to positions.

Upon stretching, the extension of the chromosome is not uniform, as compared with the spacing of bands in unstretched chromosomes, but is greatest in the lightest-staining regions and least in the heaviest-staining regions. Similarly, the light regions become relatively smaller in cross section. The stained lines do not elongate with stretching of the chromosome but move farther apart and separate into components. Hence the band material is much more rigid and inelastic than the material between, and the strength

is proportional to the staining capacity, in other words, to the concentration of nucleic acid.

A revision has also been made by Bridges of the linkage maps of all four chromosomes. This revision starts from the well-established positions of the best mutants according to the basic maps published in 1925 in *Bibliographia genetica*, p. 92, and relocates the mutants found since then by interpolation between these anchor positions. Besides the conventional line map with

TABLE 1—Coefficients of mutation and of crossing-over

Region	Microns	Mutants	Coef-M <sup>S</sup>	Coef-M <sup>N</sup>	C-O units	Coef-C <sup>S</sup>	Coef-C <sup>N</sup>
X							
0-w.....	25	20	1.7	2.3	1.5	0.2	0.3
w-ec.....	5	7	2.9	4.0	4.0	2.3	2.9
ec-ct.....	35	20	1.2	1.7	14.5	1.4	1.8
ct-v.....	37	14	0.8	1.1	13.0	1.2	1.5
v-f.....	74	27	0.8	1.1	23.7	1.1	1.3
f-end.....	44	15	0.7	1.0	9.3	1.2	1.5
Total.....	220	103	(1.0)	1.35	66.0	(1.0)	1.25
2							
0-dp.....	61	14	1.1	0.7	13.0	0.9	0.9
dp-b.....	89	20	1.0	0.7	35.5	1.7	1.7
b-lt.....	66	16	1.1	0.7	6.5	0.4	0.4
lt-msf.....	12	11	4.0	2.6	2.0	0.7	0.7
msf-vg.....	86	7	0.4	0.3	10.0	0.5	0.5
vg-px.....	122	24	0.9	0.6	33.5	1.2	1.2
px-end.....	26	14	2.3	1.6	7.5	1.2	1.2
Total.....	460	106	(1.0)	0.66	108.0	(1.0)	1.00
3							
0-h.....	71	12	0.9	0.5	26.5	1.7	1.6
h-Ly.....	36	15	2.2	1.2	13.9	1.8	1.7
Ly-st.....	32	6	1.0	0.6	3.6	0.5	0.5
st-in.....	71	4	0.3	0.2	2.0	0.1	0.1
in-p.....	66	8	0.6	0.4	2.0	0.1	0.1
p-sr.....	73	18	1.3	0.7	14.0	0.9	0.8
sr-e.....	22	9	2.2	1.2	8.7	1.8	1.7
e-ca.....	97	19	1.1	0.6	30.0	1.4	1.3
ca-end.....	27	2	0.4	0.2	9.3	1.5	1.4
Total.....	495	93	(1.0)	0.55	110.0	(1.0)	0.96
4							
0-end.....	15	8	1.0	1.50	0.2	1.0	0.04
Total.....	15	8	(1.0)	1.50	0.2	(1.0)	0.04

crossbars leading to locus numbers and to symbols, a more generally useful form of map has been prepared as a serial list of locations for each chromosome, giving, besides the locus and symbol, the full name of each mutant, a brief description of the somatic and genetic features, and finally a valuation index which tells the relative usefulness of each mutant and the reliability of its localization.

The correlation of these two types of map, the linkage map and the salivary map, is proceeding rapidly. Many new correspondence points have been established by salivary analysis of mutants that are aberrations of one type or another, the most useful being the deficiencies.

With the aid of these correspondence points a preliminary survey has been made of all four chromosomes as to the relative mutability and relative frequency of crossing-over shown along their respective lengths. The loci of visible mutations whose localization is fairly reliable total 410 for the four maps, distributed as follows: X = 103, 2 = 106, 3 = 93, 4 = 8 (see table 1). The lengths of the salivary chromosomes in the 1935 map were: X = 220, 2 = 460, 3 = 495 (adding 10  $\mu$  for unmapped chromocentric region of 3), and 4 = 15  $\mu$ , totaling 1190  $\mu$ . This gives an average frequency of 0.35 mutations per  $\mu$ . The X, with 103 mutants in 220  $\mu$ , has a frequency of 0.47 mutants per  $\mu$ , which is 35 per cent higher than the average of 0.35. The coefficient of mutation to the base N (total of mutations for the entire group of chromosomes) is thus: 1.35 for X, 0.66 for 2, 0.55 for 3, and 1.5 for 4. The relative mutability of the X is apparently over twice as high as that of the two large autosomes, but this apparent difference is not real, being due mainly to the greater ease of discovery of sex-linked as compared with autosomal mutants.

Within any particular chromosome no such difference in ease of discovery exists. The regional differences within each chromosome can be calculated from the relation between the lengths in  $\mu$  between correspondence points and the number of mutants between these same points. Thus, in table 1 the coefficients of mutation to the base of the same chromosome (Coef- $M^s$ ) give the local variations accurately.

Similarly, from the relation between the lengths in  $\mu$  between correspondence points and the number of crossover units between these same points, coefficients of crossing-over to the base of the same individual chromosome (Coef- $C^s$ ) or the entire group (Coef- $C^N$ ) have been calculated (table 1).

It is apparent that local frequency of mutation and of crossing-over are two nearly independent variables, as they should be on the assumption that mutation is a function of the genes and crossing-over of the intergenic connections. But, nevertheless, the highest point of mutation and of crossing-over are in the region just to the right of white, while the lowest crossing-over (except for chromosome 4) is near the spindle attachment of 3, where mutation is also very low.

The salivary analysis of the familiar inversions and balancers for chromosomes 2 and 3 has been carried nearly to completion by Bridges with the co-operation of Dr. J. C. Li, of Yenching University. The inversion labeled In(2L)t, dp<sup>2</sup> pr (stocks 414 and 432; DIS-7:28) has now been found to be the product of simple crossing-over between In(2L)Cy and In(2L)t and is the type deficient for both differences between them (see last year's report,

Year Book No. 35, p. 292). This balancer has been found by Mrs. Viola Curry to act as a Suppressor of Star and is now called In(2L)Cyt, Su-S dp<sup>2</sup> pr. The homozygous inversion called In(2L)t, b pr (stock 724; DIS-7:32) has been found to be In(2L)Cy, b pr instead. A new second-chromosome inversion In(2LR)dp has eight breaks involving both left and right limbs, and the complex rearrangement of parts makes it a perfect balancer for the region from locus 15 to 65 including the mid-region of 2.

The first inversion of chromosome 3, called In(3R)C, has been reported as a simple inversion of a free end, involving only one break. Renewed study shows that there are two breaks, one just before the heavy capsule of 92E (94E given previously was a clerical error) and another following 100F1, leaving a tiny cap of 3 lines beyond the inversion. Thus, this case is not an exception to Muller's assumption that inversions require two breaks.

Renewed study of the Payne inversions shows that the left break of In(3L)P lies in the middle of the faint-band region of 63C (not 64B as previously believed) and the right break probably splits the doublet beginning 72E. The inversions with gleam, Moiré, and mottled are all In(3L)P. The balancer "LVM" has both Payne inversions but has different lethals from "Payne" itself, for Payne/LVM is fully viable. In(3R)P without any lethal is common, having been scattered widely from the Florida wild and white stocks, both of which carried In(3R)P/lethal. In(3R)M, In(3R)N (supposedly In(3L)N), In(3R)spr, In(3R)ven, and In(3R)Woodbury are all In(3R)P.

In the course of making salivary analyses of all dominant mutations available, Bridges has found that the much-used dominant Dichæte, and its allel D<sup>3</sup>, are both associated with a short inversion of 3L. The left break of In(3L)D follows the heavy capsule of 69D and the right break precedes the medium doublet of 70D1-2. This inversion prevents crossing-over in its extent and close neighborhood and explains the apparent clumping of unlike mutants at 40.4. The inversion makes D and D<sup>3</sup> unfit for linkage work and means the loss of many data collected in the past. The place of D is fortunately filled by Glued, which has apparently normal salivaries; and, in cases where Glued cannot be used, by Lyra. Lyra is a deficiency, but of a section so tiny that the disturbance to crossing-over is probably negligible. The deficiency of Lyra removes from subdivision 70A the faint line 70A3 and the strong doublet 70A4-5, leaving the very strong doublet 70A1-2 and the final faint 70A6. The otherwise excellent dominant Humeral involves two short inversions in tandem, the three breaks being (1) after the heavy band of 84B, (2) after 84F2, and (3) before 86C. The dominant (♂-sterile) Bubble is associated with a 1-3 translocation whose breaks are at 13E and 84F. Mutants whose salivaries are apparently normal include S, Mz, dp<sup>ix</sup>, dp<sup>r</sup>, Sk, Sp, J, Ml<sup>2</sup>, Gl, Dfd, Sb, and H.

The third-chromosome "balancer" made at Austin by X-raying Dichæte (called Cx,D or D,cx) has In(3L)D and five other breaks, at 72A, 80D, 84F, 85E, and 95F. This is the best balancer for the mid-region of 3, from D to somewhat beyond H. The balancer Moiré<sup>ix</sup>, which is better called T(2;3)Mé, was similarly made at Austin by X-raying Mé with its In(3L)P. Salivary examination by Whittinghill (unpublished) shows six additional



breaks and such a complex rearrangement as to make this the best balancer so far known for holding the entire chromosome 3.

Study of the characteristics of variegation types associated with rearrangements involving heterochromatic chromosome regions has been continued by Schultz. Salivary observations on certain of these translocations show, as reported last year, that variegation is correlated with the loss from some cells of genes newly transposed to heterochromatin. This year's work has been concerned with following out various implications of eversporting somatic deficiency.

The number of genes lost varies according to temperature, Y-chromosome balance, and miscellaneous genetic modifiers. One genetic modifier of particular interest (located in the third chromosome, salivaries apparently normal) exercises a dominant maternal effect for the suppression of variegation. One of the most striking effects is the change in variegation which occurs in the combinations of different eversporting rearrangements. Neglect of this interaction has led Dubinin into erroneous interpretations in a recent paper. He concluded that the Plum rearrangement is a particularly mutable one, giving 4 per cent of changes in variegation type at a dosage of 4000 r-units. All these were associated with new chromosome rearrangements, most of them in the heterochromatin of 2R. Unpublished data of Dr. D. G. Catcheside give for normal chromosomes rayed at 4000 r-units this same 4 per cent frequency of rearrangements for this region. Evidently Dubinin's "mutability" and "new type of position effect" may be interpreted as the result of combining two rearrangements—the original Plum, and the new one induced in the same chromosome. Moreover, effects entirely comparable to those he describes have been obtained by combining either white or brown variegations with each other.

As stated above, the band deficiencies observed in variegated types are of different extents in the same gland. The question arose whether the longer deficiencies are the progeny of cells already carrying shorter ones; in other words, whether the process giving rise to variegation occurs at more than one cell division. This was answered by observation of the pattern where two mutant genes, white and roughest, affected the eye, with roughest closest to the break. If the longer deficiencies came from cells in which there already was a shorter one, the primary patches in the eye should be roughest, with secondary white roughest patches included, and this was the case. The not-roughest areas never showed eye-color variegation. A still more sensitive test, interesting on its own account, is provided by the color of the secondary patches involving white. When only relatively short deficiencies are produced, the eye-color change resembles one of the darker allelomorphs of white. As the genes closer to the white locus are also lost, by longer deficiencies, the phenotype passes through the lighter allelomorphs, until the full effect of white may be produced. The relation between the lightness of the white allelomorph and the fewness of genes left between white and the break is similar to other cases of position effect. For example, in the brown variegations it has now been found, with the localization of brown in a brown deficiency at 59E3-F1, that the closer the position of the break to the brown locus, the more extreme the dominant brown phenotype. It seems that the

comparison of variegations with "ordinary mutations" at these loci is somewhat precarious at present; for example, the most frequent stable allelomorph of the white locus is white itself. But in the white-variegated types, a creamlike color is most frequent, occurring in eight out of twelve cases studied. These creams include breaks in the heterochromatin of X, 2L, 3L, and 4. In one case of white phenotype the break occurred in 3R heterochromatin, involving a small inversion, from 71D4 to 81A, associated with the intercalation of a portion of X (2C2 to 3C4) within the heterochromatic region. Two additional cases involving attachments of tip of X to 2R heterochromatin do not show color variegation, although they do show variegation for split and roughest. These two cases are similar to Grueneberg's roughest<sup>3</sup> inversion, where the roughest phenotype is partially suppressed by the Y.

The evidence is not inconsistent with the idea advanced several years ago that these variegation deficiencies are the result of gene reproduction in special types of configuration, possibly due to a cytological position effect, from the nonhomologous attractions of heterochromatic regions.

Some of the variegations examined have not shown visible deficiencies in the salivaries, although the variegation follows about the same rules as the others that do show visible losses. However, it seems probable from the pattern shown (pepper-and-salt in the eye, single bristles on the body) that the cases not showing visible deficiencies may undergo variegation at a rather late developmental stage, i.e. not until the imaginal cell-divisions. Since the difficulty of demonstrating a single band deficiency, particularly near heterochromatic regions, is considerable, it would appear from these considerations that such cases are not yet useful for critical work.

In the majority of these variegations, the interpretation is that the non-deficient areas are wild type, and the deficient areas mutant type. An exception is the variegation at the "light" locus, where complete suppression of variegation results in an eye indistinguishable from homozygous light. In the variegated light stocks (three associated with a brown variegation, one with a variegated white) the Malpighian tubules should be homogeneously colored, if the egg contained the normal allelomorph of light; for Beadle has shown that light progeny from mothers only heterozygous for light have colored tubules (maternal effect). But in fact they are variegated, hence it must be concluded, as was previously assumed on other grounds, that the direction of mutation is from light to wild type.

The variegated stocks, while interesting in themselves, are also useful as tools for the analysis of special developmental problems. The variegation for white in Malpighian tubules is all-or-none for the cytoplasm of individual cells, and is especially clear after staining with toluidin blue or neutral red. If the differential process affected by the white gene occurred prior to division it should give rise to two daughter cells of the new constitution. On the other hand, if the cytoplasmic differentiation occurs after or during the separation of the nuclei, one of the daughter cells will be of the new, the other of the old constitution. Fifteen cases of tubules in which only a single cell was white were found, among a total of fifty examined, from individuals whose genetic constitution was such that variegation was at a minimum. It follows that the cytoplasmic difference between the white and normal cells

is established during the so-called "resting stage," i.e. after telophase, and before the breakdown of the nuclear membrane at the following metaphase. It is of further interest that the cytoplasmic differences here involved (the yellow pigment bodies) are "formed elements," which are related to the Golgi bodies by some cytologists.

For the salivary study of variegation in the white region, it was found desirable to become familiar with the characteristics of the normal salivary gland chromosome and with some of the mutants of this region. White had already been localized by Mackensen in the second heavy band of 3C, a localization confirmed by numerous other investigators. In addition, roughest<sup>2</sup> has been reported recently to be a deficiency for one of the other heavy bands in this region (Emmens), and the facet-split-Notch complex has been localized by a number of workers as the fourth heavy band of 3C. These workers agree as to the difficulty of observation in this region, and a number of them have suggested that the clumping is due to a duplicate section. Support for such a hypothesis would be offered by the disappearance of the buckle characteristic of the normal chromosome when one of the duplicated loci was removed in some rearrangement or other. This has been found to be the case in fact, in the study of the roughest<sup>2</sup> deficiency, which removed the third heavy band of C3, and of the deficiency in the white variegation "cobbled," which has the first band of 2B next to the fourth heavy band of 3C with the intermediate section excised. It seems likely that the presence of apparently nonallelomorphic genes, such as facet and split, in juxtaposition to each other may be the result of the duplication and resultant position effects.

By the use of heterozygotes for closed-X chromosomes, in which the white mutant was present either in the rod or in the closed-X, it was possible to get preparations in which both haploid strands could be compared in the same nucleus. It appears that in properly stretched preparations the second heavy band of section 3C is somewhat thinner in white than in normal. A more striking effect of white is that of increasing the frequency of intra-chromosomal synapsis (clumping) of the duplicated sections from the wild-

TABLE 2—The frequency of intrachromosomal pairing (clumping) in the white region of the salivary gland chromosomes of various heterozygotes for white, its normal allelomorph, and the roughest<sup>2</sup> deficiency

	+X <sup>c</sup>		+		wX <sup>c2</sup>		w		rst <sup>2</sup>		Homo- logues paired	Unan- alyzed
	Paired	Not paired	Paired	Not paired	Paired	Not paired	Paired	Not paired	Paired	Not paired		
+X <sup>c2</sup> /+.....	16	19	17	17	.....	.....	.....	.....	.....	.....	103	136
+X <sup>c2</sup> /w.....	11	9	.....	.....	.....	.....	17	6	.....	.....	7	29
+X <sup>c1</sup> /w.....	10	8	.....	.....	.....	.....	19	6	.....	.....	49	84
wX <sup>c2</sup> /+.....	.....	.....	36	37	48	16	.....	.....	.....	.....	37	64
wX <sup>c2</sup> /rst <sup>2</sup> .....	.....	.....	.....	.....	48	14	.....	.....	9	56	53+	41+
Total.....	37	36	53	54	96	30	36	12	9	56	219	354
Percentage paired.....	50.6		49.5		76.2		75.0		13.8			

type incidence of about 50 per cent to about 75 per cent (table 2). Presumably the local size difference between the bands of white and normal is responsible for the difference in frequency of association of the two outer bands.

The size difference apparent in the white mutation might be a deficiency for part of a band or a change in molecular structure such that the ability to combine with nucleic acid, or to grow to the same size as the normal allelomorph, is decreased.

The cytological work of Heitz and the genetical work of Kozhevnikov had indicated that the two species *simulans* and *melanogaster* differ in their heterochromatic regions, *simulans* having considerably less X heterochromatin than *melanogaster*. Accordingly, matings were made of the variegated types Plum-1 and Plum-2 of *melanogaster* to *simulans*. The Plum variegation was suppressed in the hybrids with a normal Y-chromosome balance. In XO hybrids, however, the mottling was evident, showing an effect of the Y on variegation in the hybrids.

In the course of these experiments, two new types of hybrids were found: triploids containing two *simulans* and one *melanogaster* sets of chromosomes, and diploids with two *simulans* second chromosomes and hybrid X and third chromosomes, resulting from simultaneous nondisjunction of the second chromosome of both parents. Both types were sterile, and the diploid was very weak.

In collaboration with Dr. D. G. Catcheside, Schultz has studied the cytological characteristics of the two closed-X chromosomes of spontaneous origin in *Drosophila*. They turn out to be deficiencies at the left end (subdivision 1A) and duplications at the spindle-attachment end. This is consistent with their origin by translocation between the two arms of the attached X's in their mothers, and brings these two hitherto isolated cases in line with the general information concerning chromosome rearrangements.



## EMBRYOLOGY

Hertig, Arthur T., Boston Lying-in Hospital, Boston, Massachusetts. *Research in embryological pathology.*

With financial assistance from the Carnegie Corporation of New York, an extended study of various aspects of the pathology of the human chorion has been undertaken. This study is in charge of Dr. Arthur T. Hertig, Assistant Pathologist of the Boston Lying-in Hospital, with the collaboration of Dr. George L. Streeter, of the Department of Embryology of the Carnegie Institution. The grant has been used almost entirely for technical assistance, which has been rendered by Miss Frances Irving.

The investigative work this year has been carried on by Dr. Hugh H. Nuckols, a Research Fellow in the Department of Obstetrics of the Harvard Medical School, under the general supervision of Dr. Hertig.

The phases of hydatid degeneration studied this past year have included control studies by gross stereo-photography, serial sections, and reconstructions on normal chorionic villi of an age comparable to those in which hydatid degeneration usually develops, i.e. 8 to 12 weeks. These researches were done mainly to determine the general morphology of the villi, but more especially their vascular pattern, since it is generally agreed that a change occurs in the vessels of chorionic villi which are the seat of hydatid degeneration. It may be said in summary that the vascular pattern at this time is one of central large vessels without anastomoses giving rise to peripheral capillary networks with many anastomoses.

The Langhans epithelium of these relatively early villi was also studied for evidence of any relationship to angiogenesis similar to the relationship found in very early chorionic villi by Hertig in 1935 (Carnegie Institution of Washington Publication No. 459, Contributions to Embryology, vol. 25, no. 146). No evidence of continued angiogenic activity on the part of the Langhans epithelium was found in these 8- to 12-weeks-old villi.

It has been found in this study of normal early chorions that certain villi show submicroscopic changes (i.e. visible with the binocular microscope) that resemble hydatid change. The portions of the villus so involved are irregularly swollen with attenuated connections to the rest of the villus. Serial sections of such villi reveal a swelling of the stroma with discontinuity of vascular structures similar to that seen in the hydatid villi of definitely pathological ova. It is impossible to tell from these initial studies whether stromal changes initiate the general process of hydatid change or whether the vessels persist in the disconnected phase as is normal for the very early chorionic villi (Hertig, *op. cit.*). In any study of hydatid degeneration it seems to us that such a fundamental morphological point must be cleared up before the true nature of the hydatid degeneration can be fully understood. Further work in this respect we hope will elucidate this point. A few early pathological chorions of 8 to 12 weeks showing hydatid change have been studied by serial sections and have shown the presence of a discontinuous endothelial phase, or it may be secondary to the changes in the stroma which result in the accumulation of intercellular material, the exact

nature of which is in dispute. Here, likewise, we hope that through studies of more closely graduated stages of hydatid change on early pathological chorions we may determine the sequence of events in this type of degeneration.

Dr. Nuckols has compiled a complete bibliography on hydatid degeneration and hydatidiform moles up to 1936 to aid in this study.

Effort is being made, as part of this general study of hydatid degeneration, to obtain for study hydatidiform moles, the clinical and pathological manifestation of hydatid degeneration, which is of considerable clinical importance. Material from over one hundred cases of this relatively uncommon condition, from all over the country, have been made available for study in the pathological laboratory at the Boston Lying-in Hospital. An attempt is being made to classify epithelial changes and correlate them with respect to the subsequent outcome of the patient so that malignant and potentially malignant hydatid moles may be diagnosed earlier and hence more adequately treated.

## GENETICS

Babcock, E. B., University of California Agricultural Experiment Station, Berkeley, California. *Cytogenetic and taxonomic investigations in the Crepidinæ*. (For previous reports see Year Books Nos. 25-35.)

The subtribe Crepidinæ is one of the five subdivisions of the Cichorieæ, the tribe which includes all species of the Compositæ having only ligulate florets in the flower head. There are some 30 genera in the Crepidinæ, the largest and best known being *Hieracium*, *Crepis*, and *Lactuca*. Other smaller but well-known genera in this subtribe are *Taraxacum*, *Sonchus*, and *Prenanthes*. As an outgrowth of earlier studies on *Crepis*, the problem of phyletic relations between *Crepis* and these nearly related genera has made necessary a survey of the cyto-taxonomy of all these larger genera together with as many as possible of the smaller genera comprising the subtribe. During the past year 71 species from 18 genera of the Crepidinæ have been cultivated and cytological studies are in progress. At the same time 44 species representing 19 genera of the other four subtribes of the Cichorieæ have been acquired in order to give a broader view of the chromosome relations within the tribe as a whole. By this method of attack it is anticipated that a more natural systematic treatment of the Cichorieæ, especially the Crepidinæ, can be worked out. At the same time more intensive studies on certain of the larger genera are being continued.

*Youngia*—The monograph mentioned in the previous report (Year Book No. 35) is in press. It will be published as Carnegie Institution of Washington Publication No. 484.

*Crepis*—The monograph on this genus is well advanced but cannot be ready for publication before sometime in 1938.

*The American species of Crepis*—The peculiar problems involved in reaching a satisfactory systematic treatment of the native American species of *Crepis* were briefly discussed in the preceding report, and the special methods devised in working out these problems were described. This work has been continued and another field trip is being made to obtain more data on the distribution of diploid and polyploid races in relation to topographic, edaphic, and climatic factors. A cyto-taxonomic revision of these species is nearly ready for publication.

*Lactuca*—About 50 species of *Lactuca* have been cultivated and their chromosomes have been examined. The prevailing haploid numbers are 8 and 9, but all except one of the native American species yet studied are polyploid. They are of interest in that their haploid number, 17, is the sum of the two numbers found among the European species, which suggests hybridization followed by amphidiploidy as the mode of origin for the American representatives of this genus—a similar situation to that which obtains in *Crepis*.

*Prenanthes*—As was stated in the previous report, more difficulty has been met in obtaining living material of *Prenanthes*; but a taxonomic revision with special reference to the eastern Asiatic species is in progress. Cytologically the species are very similar to one another, since all (except one

polyploid) have as the haploid number either 8 or 9 and the chromosomes are closely similar in size and morphology.

*African Crepidinæ*—Through the courtesy of Dr. W. A. Robyns, Directeur, Jardin Botanique de l'État, Bruxelles, we have undertaken the identification of the Cichorieæ from the Belgian Congo. A special study has been made by Babcock of the *Crepis* species of western tropical Africa (see bibliography); and one by Stebbins of certain species of *Lactuca* and *Prenanthes* from the Parc National Albert which is nearly ready for publication. Among the new species described in the latter study is one of *Prenanthes* which brings out an interesting relationship between the flora of the mountains of tropical Africa and that of the Himalayan region.

*Cytogenetic studies*—Eleven new first-generation hybrids between *Crepis* species have been grown during the year. These are being studied with reference to comparative morphology, somatic chromosome number and morphology, meiotic chromosome behavior, and fertility. In addition a study of later generations descended from the original plant of *Crepis artificialis* is being made in order to determine the amount of irregularity in chromosome distribution and its bearing on the production of potential new species. The original *artificialis* plant was a balanced hybrid derivative from *Crepis setosa* ( $2n = 8$ )  $\times$  *C. biennis* ( $2n = 40$ ) which contained 10 pairs of *biennis* chromosomes and 2 pairs of *setosa* chromosomes. Up to the present 12 plants have been examined: 4 third-generation plants all had the "normal" ( $2n = 24$ ) somatic chromosome number of *C. artificialis*; 7 fifth-generation plants had the numbers 20, 23, 25, 26, 29, 33, 34; and 1 sixth-generation plant had 34 chromosomes. An attempt is being made to establish true-breeding lines from some of these plants.

During the past year the writer has been assisted in the Crepidinæ investigations by Dr. G. L. Stebbins Jr., taxonomist and cytogeneticist; Dr. J. A. Jenkins, cytologist and geneticist; Mr. E. Jund, technician; Miss Anna Hamilton and Mrs. Katherine Jenkins, artists.

**Banta, A. M.**, Brown University, Providence, Rhode Island. *Preparation of report on Cladocera studies.*

The year 1936–1937 has been spent, with the efficient help of Miss Thelma R. Wood, in intensive work in preparation of manuscript of unpublished and inadequately published studies upon Cladocera made at the Department of Genetics of the Carnegie Institution, with which have been included certain studies by the writer and students at Brown University.

Information obtained and interpretations derived from our studies, now prepared in manuscript form, may be briefly mentioned as follows:

1. Selection was shown to be effective in clones of Cladocera with such diverse characters as reactivity to light, sex intergradedness, and head form.

2. Contrary to the long-standing belief that Cladocera cannot for long continue to reproduce by parthenogenesis, we have found that parthenogenesis per se has no ill effects and may continue indefinitely. Mutations do sometimes arise which render a clone vegetatively and reproductively



weak. Such mutations are not however caused by parthenogenesis; they have no relation to the length of the previous period of parthenogenesis.

3. Contrary, likewise, to the long-credited hypothesis that there is in Cladocera a recurrent sexual cycle controlled by internal factors, we found (as the work of others had already in part suggested) that male and sexual-egg production are controlled by environmental factors. With *Moina macrocopa*, with which we have worked intensively (with the exceedingly competent collaboration of Dr. L. A. Brown), we became convinced that male and sexual-egg production are controlled solely by environmental factors. Among the factors causing male production are the effects of the accumulation of excretory products, temperature, quantity of food, and certain drugs, all of which cause male production apparently by lowering the rate of metabolism of the mother and the ovarian eggs. The effective period is shortly before egg-laying. Sexual-egg production is stimulated by a still lower rate of metabolism associated, at least usually, with food scarcity.

4. Different species, races, and even clones of Cladocera differ in their tendency to give rise to males (and sexual eggs). Some, e.g. *Moina macrocopa*, very readily yield to male-inducing influences. Others, e.g. *Daphnia magna* and *Moina affinis*, much less readily produce males. These differences clearly are hereditary. Certain sexually produced individuals produced only male parthenogenetic offspring; obviously such individuals could not give rise to clones. Other sexually produced individuals (and clones derived from them) gave rise to high percentages of males among their parthenogenetic offspring and, like the all-male-producers, did so under conditions which ordinarily are associated with all-female parthenogenetic young. It is clear that in *Daphnia* there are genetic factors which control or influence the tendency to produce males.

5. The advantages of parthenogenesis have been utilized by evolution to such an extent that increasingly specialized types of Cladocera have more and more limited occurrence of the non-egg-producing male, until in the most highly specialized type the capacity for production of males has become lost and even the indispensable winter eggs are parthenogenetic. In such races the advantages of recombination in sexual reproduction have been lost. However, the occurrence of such forms at Cold Spring Harbor and in the far-away Arctic apparently certifies to their success.

6. Diploid parthenogenesis theoretically should render the members of a clone genetically uniform. We have demonstrated that the members of a clone are relatively constant in morphological and physiological characteristics. This demonstration is based upon (a) study of morphological characters (some of which are variable in their expression, though genotypically the members of a clone are uniform) within a clone, (b) detailed growth studies, (c) studies on oxygen consumption, (d) careful analyses of reproductive characteristics, and (e) study of certain general physiological characteristics, including thermalness and longevity.

7. Mutations appear in Cladocera both during parthenogenesis and in sexual reproduction. We have obtained as morphological mutations occurring during parthenogenesis sex intergradedness in *Simocephalus exspinosus* and sex intergradedness, excavated head, and short beak in *Daphnia longi-*

*spina*. These phenotypically variable morphological characters are influenced in their expression by environmental factors. They are also influenced by modifying factors, as our results of selection and studies on inheritance in sexual reproduction clearly indicate. Recurrences of the sex-intergrade and excavated-head mutations during parthenogenesis are moderately frequent.

8. After having worked out the fairly simple but rather exacting technique of securing males and sexual eggs, we proceeded with studies in inheritance in sexual reproduction with *Daphnia longispina*. Some results of these studies are stated in paragraphs 9 to 14 following.

9. Sex intergradedness, excavated head, and short beak were shown to be dominant mutations, influenced in their average grade of expression by accessory mutant factors.

10. The cladoceran male was, as the result of mating the mutant male with several normal females, found to produce substantially equal numbers of offspring carrying the mutant character and normal offspring. This settled the question of diploidy of the male, inasmuch as a haploid male could not give rise to two classes of sperm.

11. Recessive mutations which occur and accumulate during continued (diploid) parthenogenesis make their presence known in the results of inbreeding within a clone. Excellent presumptive evidence of a surprising frequency of such mutations was obtained—lethals, sublethals, and others. Successive inbreedings of the same clone demonstrated that the longer a clone continued by parthenogenesis, the more of these recessives it carried. These recessive mutant factors revealed their effects in lowered hatchability of sexual eggs, and in the hatched offspring—decreased viability, increased sterility of viable individuals, and a wide range of vegetative vigor and reproductive capacity in fertile individuals.

12. Mutations are fairly frequent in sexual reproduction. Moderately large numbers of sexually produced offspring provided evidence that sex intergradedness appears as a spontaneous mutation in about 22 of 1000 sexual offspring; excavated head in about 8 of 1000 sexual offspring.

13. Thermalness, another presumably dominant mutation, has occurred (or at least has been recognized) only once. The origin of the thermal clone is suggestive of the probable method of origin of thermal races in natural thermal waters.

14. Slow development and dwarfness were recessive mutations of unusual interest which arose during parthenogenesis and were revealed in sexually produced offspring. Individuals of clones possessing these characters produced growth curves characteristically different from normal growth curves.

15. Among the results obtained were some which we think are suggestive of cytoplasmic transmission. (a) Reciprocal crosses with the sex-intergrade and excavated-head characters in *Daphnia longispina* produced results which, we think, were probably not due to sex-linked accessory factors and suggest that when carried by the egg cell, rather than by the sperm cell, sex intergradedness and excavated head both appear more frequently and at a higher average grade of expression. (b) The results of a test series, expressly planned to learn if the grade of expression of sex intergradedness

in the mother is reflected in the average grade of its expression among her parthenogenetic offspring, indicated that "high" mothers produced offspring averaging slightly, but apparently significantly, higher than "low" mothers, despite the fact that both groups of mothers were simultaneously obtained from the same clone and hence were presumably genetically identical. (c) "Return" selections with the excavated-head character, in nearly all cases promptly, produced results fairly consistently, but slightly, deviating from those of the clone from which the return selection was made. The promptness of appearance of these differences and their small magnitude, as contrasted with mutational effects recognized in selection experiments, militate against their being considered as mutations.

16. Our studies of the characteristics of different clones made it desirable to establish growth and reproductive norms for *Daphnia longispina*. An individual of a vigorous clone, although approximately doubling its volume at each molt during juvenile instars and continuing to grow for approximately 70 per cent of its life, has a limited growth. It tends to attain a fairly closely circumscribed maximum size and then to cease to grow. Before growth ceases it is already showing senescence in its reduced rate of reproduction. It often undergoes reduction in body size during its final senescent instars.

17. Growth curves of individuals of, and average growth curves for, different clones are highly characteristic and very diverse. They show characteristic differences in declivity at different points, in maximum height attained, in point of attainment of maximum height, in the point of growth cessation, in negative growth, etc.

18. There are equally striking differences in reproductive characteristics and in longevity of different clones.

19. The possibility that Cladocera have become so highly specialized that in an evolutionary sense they have run into a blind alley is considered. Any meatazoan species when critically studied seems highly specialized. It is perhaps doubtful whether Cladocera species have become more highly restricted by specialization than *Drosophila* or *Datura* species for example; and *Drosophila* and *Datura* workers have found abundant evidence of genetic changes some of which appear to have evolutionary significance. Thermalness and malelessness, the former potentially and the latter actually, are in a real sense evolutionary advances in Cladocera.

**Burks, Barbara S.**, Eugenics Record Office, Cold Spring Harbor, Long Island, New York. *Studies of available data in connection with research projects in the field of human heredity.*

The following report has been submitted with relation to studies undertaken at the Eugenics Record Office by Dr. Burks through support of funds granted by the Carnegie Corporation of New York to the Carnegie Institution of Washington.

Viewing the field of the heredity and development of psychological traits in man as still largely in a pre-Mendelian epoch, the writer has long wished to extend the scope of her former work on resemblance in parents and children, siblings and twins, in their own and in foster families, to include a



basic explanation of the Mendelian mechanisms involved. That the techniques of geneticists have been largely overlooked in the past by psychologists is probably due in part to the difficulty of identifying genes in the absence of experimental breeding material, and perhaps in part to resistance of workers in one discipline toward the techniques of another discipline.

If we think of a Mendelian analysis of human traits as the end achievement in the controversial nature-nurture problem, we may envisage the state of knowledge with respect to any aspect of human heredity as having reached a rung on a ladder leading to this end achievement. It is essential to sound Mendelian work that the traits which we employ should be measurable or definable in some objective way, and that once identified, we should know not only how they are distributed within a family pedigree, but how much, and under what conditions, the expression of the traits can be modified by environment. Thus we may make a rough outline of the necessary steps:

1. Selection and validation of methods for appraising capacities or traits in individuals (e.g. reputation, rating scales, tests, clinical diagnosis, etc.).

2. Observations of striking phenomena in family resemblance (e.g. incidence of high and low ability or of insanity in family lines; correlations between the mental traits of relatives compared with correlations between their physical traits).

3. Securing of crucial data separating the influence of heredity from the influence of environment (e.g. studies of orphanage children, of monozygotic twins reared together and apart, of foster parents and children).

4. Clarification of the mechanism of hereditary transmission through special analyses of family resemblance data (detection of cumulative and multiple effects of genes, dominance, linkage between genes, etc.).

The program undertaken by Dr. Burks during the current year was built around the availability of some 16,000 family records which have been collected at the Eugenics Record Office over a period of 25 years. To extract the maximum of value from these records has meant undertaking studies at various "developmental stages" of the nature-nurture problem as outlined above, according as the frontiers of a particular subject were in a higher or lower state of advancement. Moreover, the studies have included a wider gamut of traits than those considered "psychological," since the working out of an adequate methodology in a pioneer field which might be called "psycho-genetics" could sometimes be best effected through the preliminary study of objective structural traits.

#### STUDIES OF LINKAGE

*Autosomal linkage*—The most interesting and potentially the most significant results obtained are those on autosomal linkage—the first clear cases of linkage, other than linkage in the sex chromosome, yet found in man. Among many traits which were tried, and which gave negative results, two pairs emerged for which the results were significantly positive: congenital absence of certain teeth and hair color; myopia and eye color. With the first of these pairs, it was possible to make a numerical estimate of the crossover ratio between the two genes (13.0 to 15.5 per cent), and to derive



from the linkage data a necessary and sufficient hypothesis regarding the inheritance of hair color, whose exact mode of Mendelian transmission had not hitherto been satisfactorily explained. In the case of myopia and eye color, the existence of linkage was reliably demonstrated, but an exact treatment awaits a field study in which the clinical types of myopia can be diagnosed, and the factors contributing to eye color more carefully analyzed. It is hoped that such a field study will soon be possible. A short-term field study on families showing congenital tooth deficiency has already been undertaken with the cooperation of the Guggenheim Dental Clinic, New York. Precise data, including X-rays, are being obtained on the tooth deficiency cases, and several traits in addition to hair color are being simultaneously investigated on the hypothesis that they may belong to the same genetic series.

The work on linkage, though having considerable intrinsic interest for the field of human genetics, is of chief interest to the experimenter as a psychologist for its successful working out of a method which it is hoped may prove applicable in detecting and analyzing the basic components of mental and personality traits. A report emphasizing these possibilities was presented at the annual meeting (September 1937) of the American Psychological Association. A longer report for publication is in preparation.

*Method of detection and estimation*—A word might be added regarding the method itself, which is an adaptation of a method which the writer first devised and applied (with negative results) in 1930. It involves the comparison upon one trait of pairs of siblings who are (a) alike and (b) unlike with respect to a second trait; then reversing the procedure and comparing pairs of siblings upon the second trait when they are (a) alike and (b) un-

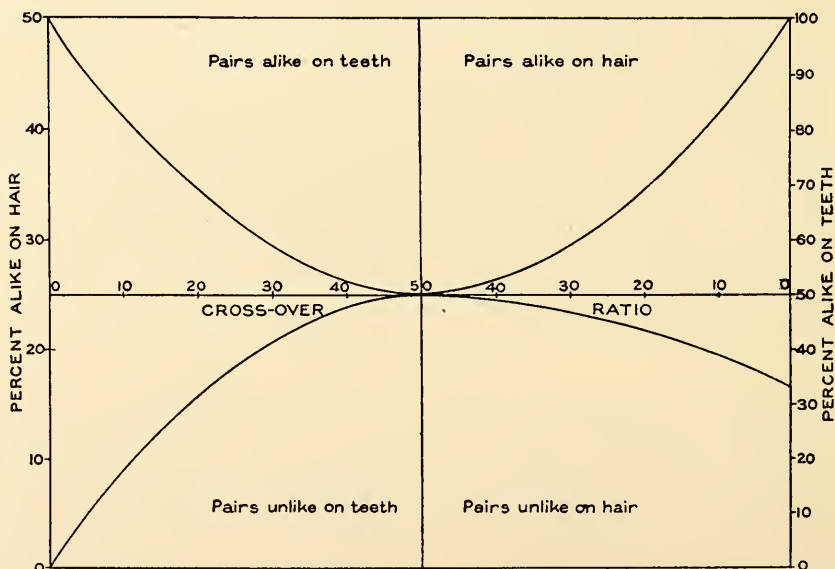


FIG. 1—For siblings alike and unlike on one trait, percentage of pairs alike on a second trait, according to crossover ratio between the traits.

like with respect to the first trait. The expected outcome, on any hypothesis regarding the genetic makeup of the two traits, can be calculated and compared with empirical data. It can be shown, also by calculation, that coincidence of the crossover values computed by means of the four comparisons is presumptive evidence for the correctness of the genetic hypothesis chosen. The unique features of the method are: (1) Data from a single generation are sufficient for an analysis of linkage relationships, though data from two or more generations can increase the yield of information from a given group of families. (2) Composite traits (i.e. traits to which two or more genes contribute) can be analyzed into their components. (3) Four different analyses provide checks upon each other; their convergence toward a single value for the determination of crossover is presumptive evidence in favor of the particular genetic hypothesis being tested, and wide disparity in the four values invalidates the hypothesis.

By way of illustration, the graphical short cut worked out for the case of tooth deficiency-hair color is here included (figure 1). In the four quadrants of the graph, crossover estimates can be read directly when the empirical data are substituted on the ordinates. The Eugenics Record Office data provided the following estimates of crossover:

13.0	13.1
14.5	15.5

These values are as close together as "sampling errors" of the data would permit.

*Incomplete sex linkage*—Looking toward the same ultimate goal of clarifying the genetic bases of psychological traits, the writer undertook also an investigation of incomplete sex linkage<sup>1</sup> in man, again upon a physical trait—retinitis pigmentosa. J. B. S. Haldane had recently published a study of the first instances of incomplete sex linkage in man ever reported. Of the five rare traits for which he found positive evidence, there was one, retinitis pigmentosa, for which the files of the Eugenics Record Office contained sufficient cases to extend and check Haldane's material. Quoting from the summary in the published study<sup>2</sup> which this work led to:

"For dominant retinitis pigmentosa we find no reason to challenge the positive results reported by Haldane, though it would be desirable to obtain further pedigrees worked out fully enough to permit a direct test of Haldane's two-gene hypothesis.

"For recessive retinitis pigmentosa with deafness, Haldane's provisional negative conclusion is corroborated.

"For recessive retinitis pigmentosa without deafness, which involves a sex-linked gene in about 15 per cent of all pedigrees according to our estimate, we do not find convincing evidence to corroborate Haldane's conclusion that an incompletely sex-linked gene is involved in the remaining cases. The discrepancy between Haldane's conclusion and ours appears to be partly due to the difficulty of excluding completely sex-linked pedigrees from those submitted to statistical treatment, and partly to

<sup>1</sup> Incomplete sex linkage occurs between genes with loci in homologous segments of the sex-determining (X-Y) chromosomes. The incidence of a gene with locus in this segment shows a normal sex ratio in the population at large, but the gene is passed on preferentially to offspring of like sex with the affected or carrier paternal grandparent.

<sup>2</sup> Retinitis pigmentosa tested for incomplete sex linkage. *Eugenical News*, vol. 22, 33-42 (May-June 1937).

Haldane's oversights in the tabulation of his data. An allelomorphous relationship between recessive and dominant retinitis pigmentosa is at the same time rendered unlikely, but the possibility that genes for recessive retinitis pigmentosa with and without deafness are autosomal allelomorphs would be well worth investigating."

As in the studies of autosomal linkage, this investigation has intrinsic interest for the field of human genetics, though it was included among the writer's research studies chiefly for the light it could give on method. In the confirmation of Haldane upon certain points, and the refutation upon another point, some of the criteria and hazards that are important in any work on incomplete sex linkage were brought into focus.

*Prospect*—In addition to the several pairs of traits which gave positive results with autosomal linkage and with incomplete sex linkage, and the larger number of pairs giving negative results, there are some pairs of traits that have been tabulated from the family records, but await analysis for the detection of linkage if present. Moreover, the time now seems ripe to attempt the application of these methods to relatively clear-cut psychological traits. It is anticipated that linkage analysis may not only permit determination of the number of genes contributing to a composite trait, but also (a) by uncovering common linkage relationships in diverse functional traits, discover which ones rightfully belong *together* under a trait name broader than that hitherto applied to any; (b) by studying progressive changes in the *apparent* closeness of linkage, find out when, and to what extent during the developmental period, differences in culture, or in the total environment as the biologist views it, introduce differences in functional traits above the native differences to be expected in a uniform environment.

#### OTHER STUDIES ON GENETIC TRANSMISSION

The research program for the year, as outlined at the time of the writer's appointment, included a study of dominance and nondominance in the transmission of multi-determined human traits. A beginning has been made on this problem, using data from the Record of Family Traits schedules in the Eugenics Record Office files, but the study has not yet progressed far enough to warrant a report on progress.

In surveying the records in the files with a view to using data upon color blindness for a test of incomplete sex linkage, several cases came to light in which the mode of inheritance was irregular, not conforming to either a complete or incomplete sex-linkage mechanism. Letters of inquiry were sent out to these cases, and among the replies were several which confirmed the data as recorded on the blanks. The possibility deserves consideration that some of these cases represent translocations of the gene for red-green color blindness from the sex chromosome to an autosome. A field study on this problem might prove profitable.

#### SIBLING RESEMBLANCE STUDY

The studies so far enumerated in this report belong with those directed toward the problem of mechanisms of hereditary transmission in man. It was suggested earlier in the report that research in human heredity can be grouped according to its place on a scale which has such genetic analysis



as its highest point. Studies of sibling resemblance belong at the second or third stage of such a scale, depending upon how the data are collected and analyzed. We have under way a study of sibling resemblance utilizing some dozens of traits included on the schedule called "Individual Analysis Card." It is proposed to use the study not only for appraising family resemblance upon a number of traits that have not hitherto been studied in this way, but also to select "promising" traits for use in linkage and other studies, and to compare the validity of ratings contributed by members of a family upon relatives of different degrees of relationship.

#### CONTROL STUDY OF FAMILY RECORDS AND TRAIT RATINGS

In connection with the sibling resemblance study briefly discussed above, and also to contribute general orientation regarding the kinds of data which are most trustworthy and most objective in studies depending upon the voluntary collaboration of families, it seemed advisable to undertake a control study. Through the cooperation of Professor Gardner Murphy, of Columbia University, who enlisted the interest of his psychology students, and through the further cooperation of members of the staff of Bennington College, it has been possible to secure duplicate family records and ratings filled out *independently* by pairs of brothers and pairs of sisters for three generations of relatives. It has also been possible to check some of the self-reports of these students against objective measures or scales (height, weight, hair color, eye color, complexion, etc.). In order to secure cooperation, the students were promised that the experimenter would assist them in the interpretation of the family histories which they compiled. Interviews held for this purpose not only revealed the distinct value that such histories have for light on eugenic and personal problems, but disclosed certain crucial points which required great caution of interpretation. It is noteworthy that with some schedules which on first reading seemed to indicate grave eugenic defects, follow-up by interview showed these to be due to specific infections or to accidents. It is also significant to note how densely ignorant of the traits of their grandparents most of these young college-educated Americans are. The data as a whole are being subjected to various analyses, and it is too early to report findings, but it is anticipated that the study will prove helpful in the planning of further work.

#### RESEARCH "OVERHEAD"

In undertaking new work with unfamiliar material, a certain amount of research "overhead" is inevitable. In the present instance, this overhead took the form of surveying the material afforded by the files on nearly two hundred traits,<sup>1</sup> surveying the relevant literature upon those traits which have been used in our studies, and trying out various ways of using the data.

<sup>1</sup> Out of approximately 3500 trait names listed in the Eugenics Record Office Trait Book, about 200 were selected for survey with respect to number and type of records which could be used. The 200 traits were chosen according to the following criteria: traits known or believed to be transmitted as Mendelian unit characters; traits, however complex, known to have a strong tendency to run in families. In compiling the list, one of the most useful sources was Dr. Laughlin's "List of characters in man classified according to their method of inheritance" (*Eugenic sterilization in the United States* [1922]).



Much of this overhead went to gaining acquaintance with the material, or trying methods which proved impracticable. Among the latter should be mentioned follow-up studies by correspondence. In the hope of getting further data upon other branches of the families of the cases showing congenital tooth deficiency and color blindness, special blanks were devised and requests mailed out. Many of the cases could not be located at all, and the returns and the additional data thus acquired were so meager that we turned to a field study to supplement the records on tooth deficiency. It is increasingly evident that field work is an indispensable supplement to research based upon family records. The records furnished a mine of material from which hypotheses can be formulated and sometimes established with fair certainty. But to obtain higher precision, particularly when traits are involved which show quantitative variation or clinical differentiation, it is necessary to see, and to assess objectively, each case included in the study.

#### PARTICIPATION OR COOPERATION IN ACTIVITIES BEARING UPON RELATED PROBLEMS

It has seemed expedient and feasible to maintain relationships with organizations and individuals whose interests lie particularly in the field of the writer's past training and experience. Frequent attendance at Professor Wertheimer's weekly evening seminar in psychological research problems at the New School of Social Research has balanced the biological emphasis of the Journal Club at Cold Spring Harbor. Various scientific meetings have been attended during the year: the Annual Exhibit of the Carnegie Institution, the biennial meeting of the Society for Research in Child Development, the December meeting of the American Association for the Advancement of Science, the Milbank Fund Conference in April, the American Eugenics Society annual meeting in May, the American Psychological Association in September. At the Milbank Conference the writer presented a paper in a symposium on measures of personal characteristics available for studies in population; at the Eugenics Society, a paper in a Round Table on the place of eugenics in our modern social system; at the Psychological Association, a paper on linkage in man and its implications for the study of psychological traits. The writer has continued to serve as a member of the Advisory Research Board of the Hudson State Industrial School for Girls, where Dr. J. Moreno's "sociometric" experiments have made a profound impress upon experimental social psychology and psychiatry. During the spring and summer consultation has continued with members of the staff of the New York State Charities Aid Association, regarding a follow-up project on foster children placed in foster homes twenty to thirty years ago.

#### IMMEDIATE PLANS

The studies on linkage open up such interesting possibilities that it seems very desirable to continue them. Data upon a number of trait pairs, other than those which have already yielded definitely positive or negative results, have been tabulated and await analysis. A field study on the linkage relation between myopia and eye color seems indicated. Especial interest attends the projected application of our method to psychological traits. In this connection it is proposed to investigate the possibility of linkage of

certain physical traits with musical ability and with cyclothymia, these being traits for which large numbers of family records are available, and which appear to have a fairly simple mode of inheritance that is not seriously obscured by cultural factors.

Studies described above upon sibling resemblance, control ratings of family traits, and dominance or nondominance in mental capacities are still being subjected to statistical treatment, and will be completed this fall.

A field study on color blindness is contemplated, to see whether any authentic cases of chromosome translocation occur in this domain.

Several studies proposed at the beginning of the year, upon assortative mating and upon large disparities in the psychological traits of families, are being held until the unfinished studies already on hand can be brought to a satisfactory conclusion.

The New York State Charities Aid Association contemplates a large-scale follow-up of its foster home placements of a generation ago from the standpoint of factors related to the physical, mental, and personality development of individuals separated during infancy from their own parents. The advantages of studying persons who have grown up under cultural influences that are quite independent of their biological inheritance, in order to establish the limits within which nature and nurture function, have been recognized and capitalized by a few experimenters in the past. The proposed State Charities Aid project would be more extensive and more intensive than any of the previous studies of foster children.

Dr. Streeter, Dr. Blakeslee, Dr. Laughlin, Dr. Davenport, and Dr. Bridges, of the Carnegie Institution, have extended many courtesies and given helpful counsel. Miss Natalie Raymond, field assistant, and Mrs. Frances Carlson and Miss Catherine Gackstatter, office assistants, have made indispensable contributions.

**Davenport, Charles B.,** Cold Spring Harbor, Long Island, New York. *Investigation on child development.* (For previous reports see Year Books Nos. 34, 35.)

During the year under review the writer has continued and brought to a conclusion the observations on child development made during three years at the Normal Child Development Study, Columbia University. The studies at Letchworth Village have been reduced from three days per month to one day. The most efficient cooperation was given at both institutions in these studies.

In connection with the work on infants, the measurements on the major dimensions of 37 babies have been tabulated and typed ready for reproduction by photography in about 74 tables. Also the growth curves, amounting to about 1350, have been drawn after necessary smoothing and the data thus presented are being analyzed in general fashion. On account of limited time, the detailed analysis must be left to others on the basis of the facts presented. It appears that the mean error of the measurements of the different dimensions ranges from 0.66 mm. (for foot width) to 4.87 mm. (for iliospinal height), the median error being 2.35 mm. (for sterno-vertebral diameter). The percentage error ranges from 0.62 (for head height) to 3.42

(for the length of the proximal segment of the arm), the median percentage error being 1.79 (for interspinal breadth).

In general the growth curves, plotted on an arithmetic graph, show rapid increase in the first and second postnatal months, as contrasted with a slow increase in the twelfth month. For example, the average monthly increase in sitting height for the first postnatal month is 21 mm.; for the twelfth, 4.7 mm. Chest girth shows the monthly increments of 23 mm. and 5.9 mm. at the respective ages; head length, of 7.5 mm. and 1.6 mm. respectively. In nearly all cases the high velocity of growth of dimensions characteristic of the last prenatal month is carried over into the earliest months of postnatal life and then gradually decreases. The growth retardation has been accounted for on nutritional grounds, but it seems probable that there is a diminished capacity for the tissues to utilize the available food. The two segments of the arm and those of the leg, which at birth show a nearly equal length, as in the anthropoids, promptly go separate paths, owing to differential growth rates, by which the human differences in the segments become established.

Of the dimensions, the thigh girth shows an extraordinary velocity of growth throughout a large part of the first year, in obvious preparation for locomotion. The shoulders, which are narrow at birth, possibly as an adjustment to parturition, grow with high velocity as if an inhibiting factor had been removed. Most erratic in its growth is the neck. Thick, like that of an anthropoid, at birth, it often soon becomes absolutely more slender and only toward the end of the year begins its growth as an isthmuslike connection between head and trunk.

The work on later stages in the development of organs has been largely concentrated on the nose, a characteristic human feature. In this study the way the genes do their work of bringing out hereditary, racial, and family differences is clearly shown. In monozygotic twins the course of development of all the nasal dimensions is close, or identical, so that the end result is similarity, in great detail, of their facial features.

## METEOROLOGY

**Bjerknes, V.,** Oslo, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics to practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5-35.)

Dr. V. Bjerknes reported in the last Year Book on a theoretical progress of considerable interest for the theoretical discussion of the problems of oceanography, of meteorology, and lately also of astrophysics. A review of the results was presented to the International Congress of Mathematics at Oslo, July 1936, under the title "New lines in hydrodynamics," and at the Assembly of the International Union of Geodesy and Geophysics at Edinburgh, September 1936, under the title "De l'application des théorèmes de circulation à la discussion des phénomènes atmosphériques." The subject of these addresses has now been treated in a paper "On the application of line integral theorems to the dynamics of terrestrial and cosmic vortices," now in print in *Astrophysica Norvegica*. The paper gives, first, simple demonstrations of the line integral theorems, including the two fundamental circulation theorems (I) and (II) mentioned in the previous annual report. Then a systematic series of applications are given, which lead ultimately to that theory of the general atmospheric circulation which has been developed by Dr. J. Bjerknes in chapter 17 of *Hydrodynamique physique* (see Year Book No. 31). Finally the theorems are applied to a renewed discussion of the problems which the author took up in his paper "Solar hydrodynamics" (see Year Book No. 26), namely the theory of the sunspots and of the equatorial acceleration of the sun.

The paper mentioned will be of importance for the final redaction of part III, "Dynamics," of that "Dynamical meteorology, etc.," which is the final aim of our work.

Dr. Solberg was during this winter invited to Poland, which was the largest European country in which the Norwegian methods of weather chart analysis and of weather prediction had not yet been introduced. He there gave practical instruction in these methods and gave a course of lectures on modern dynamical meteorology. These lectures will be printed in the near future, and will give a first brief review of the contribution to meteorology which has been developed under the auspices of the Carnegie Institution.

J. Bjerknes has given a communication, "The upper perturbations," now in print in the *Proceedings* of the meeting which the International Union for Geodesy and Geophysics held in Edinburgh in 1936. The essential result of the communication concerns the variations of pressure connected with the perturbations above the polar front surface. It is shown that these pressure changes result from more or less periodical convergence and divergence in the general westerly current of the upper strata. The ultimate cause of these upper perturbations lies in the tendency of the upper current to cross the tongues of polar air with a minimum of vertical motion.

The aerological investigations, from which the above results are extracted, are continued by J. Bjerknes together with E. Palmén. Case IV, February 15-17, 1935 (see Year Book No. 35), which gives the most complete three-



dimensional picture of a storm cyclone yet obtained, is still being investigated.

Dr. Godske, at the above-mentioned Edinburgh meeting, read a paper "Contribution to the theory of cyclone formation at extratropical fronts," which is in print in the *Proceedings* of the Union. A German abstract has appeared in *Meteorologische Zeitschrift*.

J. Bjerknes and C. L. Godske in the fall of 1936 began the final redaction of the new edition of part I, "Statics," of the "Dynamical meteorology"; at present 120 typewritten pages, plus figures and tables, are ready. Thermodynamics has been treated more completely than in the first edition. At present C. L. Godske is occupied with the redaction of part II, "Kinematics."

## NUTRITION

Sherman, H. C., Columbia University, New York, New York. *Relation of food to length of life.* (For previous reports see Year Books Nos. 32-35.)

The work here reported has been made possible by grants from the Carnegie Corporation of New York, through the Carnegie Institution of Washington. The year 1937 is bringing to completion the plan of research outlined in the reports of the past four years.

A research in cooperation with Dr. F. G. Benedict, upon the energy metabolism of rats in middle and old age and the effects of exercise in the latter part of the life cycle, has been completed, and will be briefly discussed for the purpose of the Year Book by Dr. Benedict in connection with reports of his other investigations of energy metabolism. The full account of these experiments, carried out by direct collaboration of the Nutrition Laboratory of the Institution and the Department of Chemistry of Columbia University, appears in the *Journal of Nutrition* for August 1937.

The experiments described in previous reports as designed to ascertain what chemical factors were concerned in the nutritional improvement of an already adequate diet which we had reported, have now been completed, and a paper embodying a report of the findings has been prepared for journal publication. Increased intakes of calcium, of vitamin A, and of the riboflavin previously called vitamin G, all appear to have contributed to the enhancement of vitality or positive health and to the increased length of life which had been shown to result from an increase in the proportion of milk in an experimental dietary which was already adequate in the accepted sense that it supports normal growth, health, reproduction, and lactation, generation after generation. (Families of laboratory rats are still thriving in the forty-second generation upon this original adequate but not optimal dietary.) From the viewpoint of the state of knowledge when these experiments were begun four years ago, it was deemed more scientific to supply the dietary enrichments of vitamins A and G (riboflavin) accompanied by their natural concomitants rather than in any such artificial form as would, in addition to questions of chemical purity, involve an assumption that no other known or unknown substance could have been a significant factor in the preceding experiments. Hence the experimental variables in the present series were calcium (as carbonate), butter fat for enrichment of the dietary in vitamin A, and skim-milk solids for enrichment in riboflavin in addition to calcium (which involved also a relatively smaller increase in the protein content of the diet, with increase of the proportion of milk protein in the food-protein mixture).

It was found that enrichment of the basal diet in vitamin A (by adding butter fat) did not increase the rate of growth (possibly because the added fat resulted in a slightly decreased intake of proteins, mineral elements, and water-soluble vitamins) but did result in apparently higher adult vitality and increased length of life.

On the other hand, enrichment of the original or basal diet (the Diet A of our previous reports) in calcium alone or calcium and butter fat did increase

the rate of growth and also resulted in enhanced adult vitality and increased length of life.

Enrichment in riboflavin (and to a relatively less extent in protein) resulted in further increase of the growth rate and of the size and handsomeness of physical appearance of the individuals throughout their lives, but did not result in their living longer or leaving more offspring than the parallel group whose dietary was enriched, to the same extent, in calcium alone. Only during the past year was riboflavin available for feeding in approximately pure form on a scale sufficient for comparative experiments of this type. These shorter experiments, while necessarily less extensive, permit a closer interpretation of the data of the experiments here chiefly discussed, and justify the conclusion that the riboflavin itself (rather than the accompanying protein or any unknown factor) was predominant in producing the results described in this paragraph as contrasted with those obtained by dietary enrichment with calcium only.

In another series of experiments the Diet B of our previous reports—the better of our two long-studied wheat and milk mixtures—has been fed with and without the addition of fresh lean beef and a fresh vegetable (string beans). These additions to the favorably proportioned but monotonous Diet B have resulted in more rapid growth and slightly larger adults with higher hemoglobin and slightly higher breeding records, but no further increase in the length of life.

These later experimental findings thus bear out the suggestion of our previous reports that there may or may not be a demonstrable relation between the nutritional acceleration of growth and the subsequent length of life, according to the nature of the original diet and of the dietary factor which is varied in the particular case. Of chief interest in its bearing upon human affairs is our repeated finding that, starting with a food supply analogous to those upon which most people actually subsist, it is possible to expedite growth and development, improve the average of adult vitality, and extend the life cycle, all in the same individuals, by such adjustments of the relative proportions of staple articles of food as to enrich the dietary as a whole in certain of its chemical factors.

Experiments with still more varied diets resulted in no further consistent improvement in nutritional well-being. Hence instead of carrying these latter throughout the entire life cycle, the available time and material will be devoted to the fuller rounding out of the program now being completed by partial chemical analyses of representative experimental animals from different diets.

Thus the completion of the experimental program as planned five years ago has answered the immediate questions then set and has also added greatly to the tangibility and significance of another problem, namely, the extent to which the chemical composition of a species varies with alterations of its nutritional environment within the limits compatible with health and with the normal perpetuation of the stock from generation to generation.

The efficient collaboration of those who have cooperated in this investigation, whether as research assistants or as volunteers, is gratefully acknowledged.

Vickery, H. B., New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3-35.)

The study of our new salt mixture in comparison with that of Osborne and Mendel has been continued and a paper describing this work is in press. The composition of the salt mixture, No. 351, is based on the observation referred to two years ago (Year Book No. 34) that an increase in rate of growth and in the percentage of ash in the dry, fat-free bones resulted if the calcium content of the diet was materially increased in proportion to the other inorganic constituents. With this alteration in composition, it became possible to reduce the proportion of salts included in the complete food. Our criteria of comparison were a daily increase of 5.0 gm. or more during the period of gain from 60 to 200 gm. body weight, and 58 to 60 per cent ash in the dry fat-free femurs of a 200-gm. male rat. As judged by these criteria, it appeared that if the daily calcium intake was maintained at approximately that furnished by 4 or 5 per cent of the original Osborne and Mendel salts in the diet, the results would be satisfactory. To provide ample margin of safety, the new salt mixture was planned so that when it formed approximately half this proportion of the diet, calcium would be furnished in approximately the same amount as by 5 per cent Osborne and Mendel salts, and the other constituents, with the exception of the trace elements, in the same quantities that are present in 1 to 2 per cent of this salt mixture. Inasmuch as the new preparation was designed to replace the Osborne and Mendel salts, all of the trace elements of the latter have been included, and copper has been supplied in addition. The mixture as a whole is enriched in these trace elements to about the same extent as it has been in calcium; this insures an adequate supply, without materially increasing the total weight of the salt mixture to be included in the diet.

The new salt mixture has the following composition:

CaCO <sub>3</sub> .....	543.00 grams
MgCO <sub>3</sub> .....	25.00
MgSO <sub>4</sub> .....	16.00
NaCl .....	69.00
KCl .....	112.00
KH <sub>2</sub> PO <sub>4</sub> .....	212.00
FePO <sub>4</sub> ·4H <sub>2</sub> O .....	20.50
KI .....	0.08
MnSO <sub>4</sub> .....	0.35
NaF .....	1.00
Al <sub>2</sub> (SO <sub>4</sub> ) <sub>3</sub> ·K <sub>2</sub> SO <sub>4</sub> .....	0.17
CuSO <sub>4</sub> .....	0.90

To prepare the salt mixture, the first seven salts are pulverized, mixed thoroughly, and suitable amounts of standard solutions of the remaining constituents are added to the mixture. After being thoroughly incorporated, the mixture is dried in an air drier for 6 to 8 hours at 80° to 85° C. and then ground to pass a 50-mesh sieve. A satisfactory product may also be made without the use of aqueous solutions and subsequent drying.



The new product was designed to be used at 2.5 per cent of the diet in place of the usual 4 per cent Osborne and Mendel salts. Inasmuch as this furnishes considerably more calcium, we have conducted comparative studies of the two mixtures, using the new salt as 2 per cent of the ration in order to subject it to a more rigorous test. With this smaller proportion of No. 351 salts in the diet, the level of calcium is not materially decreased in comparison with the Osborne and Mendel salts as ordinarily employed. The slight difference in calcium content of the two mixtures was not significant in a series of tests in which food intake and daily gain during the period from 60 to 200 grams were the same. The accompanying table shows average figures for such a comparison.

*Comparison of salt mixtures*

Salt mixture in diet		No. of rats	Daily gain (gm.)	Final weight (gm.)	Total food intake (gm.)	Total Ca intake (gm.)	Total P intake (gm.)	Ash of dry fat-free femurs (per cent)
Type	Per-centage							
351.....	2	11	5.3	199	290	1.32	1.01	58.9
Osborne-Mendel...	4	11	5.3	196	290	1.41	1.53	58.4

Reference was made last year (Year Book No. 35) to an investigation which was started a number of years ago by Professor Mendel in collaboration with Dr. E. A. Park, of the Johns Hopkins University. This experiment, a study of the optimal calcium-to-phosphorus ratio in the diet of the albino rat, grew out of an attempt to develop diets composed of purified foods on which rickets could be produced. With such diets, the significance of the level of calcium and of phosphorus, and of the ratio between the two, could be more accurately evaluated than with diets composed of natural foods. To this end two dietary procedures were used. One was based on the well-known Steenbock rachitogenic diet No. 2965, to which suitable amounts of calcium and phosphorus salts were added to produce the desired ratios. The other was a diet composed of purified foods, including the phosphorus-free protein, edestin. In order to rule out the effects of environment, the experiment was conducted in duplicate, with one set of animals in Baltimore and another in New Haven. In the series fed the modified Steenbock diets, the level of calcium was 1.25 per cent; with the edestin it was 0.6 per cent. The following ratios of calcium to phosphorus were employed in each series: 1:1, 1:0.7, 1:0.5, 1:0.3. The vitamin B complex was supplied by the addition of 200 mg. of dried yeast daily. In all series, groups of from 4 to 6 male rats 28 days old were fed the rations *ad libitum* for 30 days. As criteria of success, daily gain in weight, determination of the calcium and inorganic phosphorus of the blood serum, histological examination of the tibiae, and chemical analysis of the femurs were used.

The results of this experiment were summarized last year by Dr. Park, and as a result it seemed desirable to repeat and extend a portion of the work. His conclusions in regard to the experiment were briefly as follows: For the rats fed the modified Steenbock diets, the determination of the calcium and

inorganic phosphorus of the blood was unsatisfactory as a method of selection of the optimal calcium-to-phosphorus ratio in the diet. There was an indication that the extreme ratio (1:0.3) was inferior to the others, but there was no clue as to which of the remaining ratios was superior. The histological examination of the bones showed that good bone formation resulted with the 1:1, 1:0.7, and 1:0.5 ratios. The estimation of the A/R ratio  $\left( \frac{\text{Ash}}{\text{Fresh weight} - (\text{water} + \text{fat} + \text{ash})} \right)$  indicated superiority of the 1:0.7 ratio. However, the differences between this and the 1:0.5 and 1:1 ratio were not marked. The weight gains indicated the superiority of the 1:0.7 ratio.

In his study of these earlier experiments, Dr. Park felt that little reliance could be placed on the edestin experiments, partly because of poor growth. However, the determinations of the calcium and inorganic phosphorus of the blood serum gave results in agreement with those obtained with the modified Steenbock diets, namely that the extreme ratio was inferior. The results of the histological examination of the bones were particularly unsatisfactory inasmuch as there was wide variation within the different groups with the possible exception of the 1:1 ratio. In this group all the bones were normal. It is of interest that, in the case of the modified Steenbock diets, good bones were observed with two other ratios in addition to the 1:1. The higher calcium intake for all ratios with the modified Steenbock diets may have accounted for the fact that normal bones were produced in so many groups. With the edestin diet, the determination of the A/R ratio showed about equal success with the 1:1, 1:0.5, and 1:0.7 ratios, a result more or less in agreement with the experiments in which the modified Steenbock diets were employed, except that the 1:1 ratio gave the best results, while, with the Steenbock diet, a higher A/R ratio was observed when the ratio of calcium to phosphorus was 1:0.7. The weight gains were quite unsatisfactory, being no better than with the modified Steenbock diets; however, the best gains were made on the 1:1, 1:0.5, and 1:0.7 ratios, in the order mentioned.

Inasmuch as the use of diets composed of purified foods was the central theme of the investigation, it was unfortunate that growth with the edestin diets was unsatisfactory. More recent experience has indicated that in the original edestin diets the quantity of yeast supplied may have been a growth-limiting factor. Therefore, a supplementary series of experiments was conducted, using an edestin diet essentially like the original one, but with 400 mg. of yeast daily instead of 200 mg. Instead of the one level of calcium formerly employed, three levels were used in the later experiments, namely 0.25, 0.50, and 0.75 per cent. For each amount of calcium the following ratios of calcium to phosphorus were used: 1:1, 1:0.75, and 1:0.5. Dr. Park had felt, in connection with the older work, that the A/R ratio was the most reliable criterion; we have therefore made observations of this measure of success, in addition to rate of gain. Five rats in each group were fed the diets *ad libitum* for 30 days after weaning (21 days of age). Whereas, in the early work, the average daily gain was less than a gram, in the recent work the average was 1.9 gm. a day. Although this rate of gain is low for

animals of this colony, it is sufficiently in excess of that obtained previously to make comparisons between the calcium and phosphorus ratios possible. Under the new conditions, for all levels of calcium used, the highest growth rate (2.1 to 2.5 gm. per day), the highest bone ash (49.2 per cent for the 0.25 per cent calcium to 58.9 per cent for the 0.75 per cent calcium) and highest A/R ratios (0.97 to 1.43) were obtained when the ratio of calcium to phosphorus was 1:1.

The conclusion from the earlier study with the purified edestin diet indicates that, at the 0.6 per cent calcium level used, the ratio 1:0.7 was probably the most favorable from all points of view; from the supplementary experiments it appears that the 1:1 ratio is superior as judged by growth and bone ash. The later data also emphasize the favorable effect of increasing the amount of calcium fed, irrespective of the ratio of calcium to phosphorus.

During the past twenty years the study of the chemical composition of green leaf tissues, and the changes that take place in these under various conditions, has become an increasingly important phase of our laboratory investigations. Planned originally to furnish supplementary information required in connection with the use of leaf tissues in nutrition investigations, this work has in recent years assumed major significance. During the past year we have been engaged, with the cooperation of Dr. G. W. Pucher, of the Experiment Station staff attached to our laboratory, upon the study and preparation for publication of a large volume of data obtained in the course of experiments designed to show the effect on tobacco leaves of culture in water, in dilute glucose, and in a nutrient salt solution that provided nitrogen in the form of ammonia. Parallel experiments were conducted in continuous light and in the dark.

We referred briefly last year to the striking difference in the behavior of the malic and citric acid of the leaf tissue under these two conditions. The relationships have now been examined more fully and we have found much evidence in favor of the view that malic acid is extensively converted into citric acid during culture of these leaves in the dark. That the newly formed citric acid may arise as a by-product of protein metabolism is improbable on chemical grounds, and this possibility is practically eliminated as the result of newer experiments in which the actual quantity of citric acid formed materially exceeded the quantity of protein metabolized. That carbohydrates may have furnished the source is equally unlikely on similar grounds. On the other hand, the total organic acidity of the tissue remained constant, indicating that the increase in citric acid was accompanied by an equivalent decrease in some other acid, and furthermore, the actual quantity of citric acid formed is so related to the quantity of malic acid that disappeared as to lend considerable weight to the view that the one arose through chemical transformation of the other.

The results of the experiments in the light contrast sharply with those in continuous darkness. In light, little change in the quantities of malic and citric acids takes place. It would appear, therefore, that, under the stress occasioned by the absence of the immediate products of photosynthesis, the metabolism follows paths different from those that may perhaps be regarded as more nearly normal.



The contrast between the effects of light and of darkness is especially marked in connection with the changes in the quantity of organic solids in the leaves. Leaves exposed to light may, before chlorophyll degeneration becomes serious, increase in weight of organic solids by as much as 40 per cent of the quantity originally present, and little more than half of the newly formed solids can be accounted for by an increase in reducing substances calculated as glucose. In the dark, on the other hand, substantial loss of organic solids occurs, probably due to transformation into volatile products of metabolism. It is clear, therefore, that detached leaves in culture are the seat of many profound chemical reactions some of which, at least in the early stages and in the presence of light, are definitely anabolic in character. Photosynthesis proceeds with considerable efficiency and, if the immediate product of the classical reaction of photosynthesis is assumed to be a sugar, it is obvious that an appreciable part is carried on into other chemical combinations in which the sugar is no longer recognizable as such by the conventional method of determination of the reducing power.

The nitrogen metabolism of leaves in culture is even more complex than that of the organic acids. Some years ago we presented evidence (Carnegie Institution of Washington Publication No. 445) that the leaf protein, during culture in the dark, undergoes rapid digestion to amino acids which are in turn deaminized and the ammonia thereby produced is recombined in the form of amide nitrogen. We have now been able to show that the quantity of nitrogen that may be transformed into ammonia in this way, together with the quantity of ammonia that may arise from reduction of a part of the nitrate usually present in tobacco leaves, is adequate to account quantitatively for the nitrogen found in combination in the specific substances glutamine and asparagine. This implies that the ammonia is utilized in two distinct ways as it is produced. Half of it is employed for the synthesis of the  $\alpha$ -amino groups of potential aspartic and glutamic acids, the other half is employed for the synthesis of amide groups to form the substances asparagine and glutamine. In turn, the presence in the leaf cells of non-nitrogenous precursors of these two amides is obvious, and one of our most striking observations has to do with the behavior of these as yet unknown substances. When cultured in the dark, tobacco leaves synthesize considerable quantities of asparagine, but only a minor increase in glutamine occurs. In the light, however, both asparagine and glutamine are synthesized, the latter somewhat more copiously than the former. Clearly, therefore, the tobacco-leaf tissue normally contains a considerable store of the precursor essential for the synthesis of asparagine, but contains very little, if any, of that required for the synthesis of glutamine. On exposure of the leaves to light, however, the reactions of photosynthesis provide a substance which can serve in the presence of ammonia for the synthesis of glutamine. In these circumstances, both amides are formed and, although the reasons for this are not as yet clear, glutamine is somewhat more abundantly synthesized than is asparagine. It thus appears that both precursors are present only when the leaves are illuminated.

That this interpretation of the behavior is sound has been confirmed by results secured from leaves that were placed alternately in light and in dark-



ness for periods of 24 or 48 hours. With 24-hour alternations, glutamine synthesis was practically the same as in leaves kept continuously in light. Consequently we may infer that 24 hours of illumination gave rise to the formation of sufficient of the glutamine precursor to provide for synthesis during this period and an ensuing 24 hours of darkness at an undiminished rate over the entire period. With 48-hour alternations, however, the total glutamine synthesis was materially depressed, suggesting that the quantity of precursor synthesized during the period of illumination was inadequate to provide a store sufficient to maintain glutamine synthesis at the same rate during the successive cycles of light and darkness.

The hypothesis that the necessary precursor for asparagine synthesis is normally present is in agreement with the behavior of the leaves in continuous darkness. Asparagine is steadily formed, and the free ammonia remains at a low level for many hours. Ultimately, however, ammonia suddenly begins to accumulate. The behavior can be interpreted as indicating that the store of the asparagine precursor is adequate to provide for synthesis of asparagine for some time, but is finally depleted to such an extent that asparagine synthesis can no longer keep pace with ammonia production; accordingly, ammonia accumulates. This we believe results in lethal damage to the cells; chlorophyll degeneration sets in and many other irreversible changes become significant.

Some years ago Ruhland and Wetzel attempted to classify green plants into two groups on the basis of the type of ammonia metabolism characteristic of each. Plants such as rhubarb, oxalis, and begonia species possess highly acid saps and differ from plants with more nearly neutral saps in the manner in which ammonia is dealt with. The acid plants appear to be able to tolerate relatively high concentrations of ammonia, which is present presumably as ammonium salts of organic acids. The more nearly neutral plants, however, ordinarily transform all but a small residuum of the ammonia into one or both of the specific amides asparagine and glutamine, this process being regarded by Prianischnikow as a form of detoxication.

It has seemed a matter of considerable interest to study the metabolism of the organic acids and the amides in a species of characteristically high sap acidity. Considerable time has, therefore, been devoted to an investigation of the leaves of the rhubarb plant. Contrary to certain statements of the Leipzig investigators, we find that the malic acid both of the rhubarb and of the tobacco plants is exclusively the levorotatory isomer; no appreciable trace of inactive malic acid could be discovered. We have further found that there is no relation whatever between the quantities of any one of the three chief acids present in rhubarb leaves (oxalic, malic, and citric) and of the ammonia at any stage in the season. Our data therefore do not support the view that ammonium salts of organic acids play a part analogous to that of the amides in plants of a less acid nature. On the contrary, the rhubarb plant appears to possess an amide metabolism not essentially dissimilar from that of the tobacco plant, save that glutamine occupies the predominating position.

The distribution of the malic, citric, and oxalic acids in the petiole, main veins, and mesophyll tissues of rhubarb leaves provides an interesting example

of concentration gradients. Malic acid concentration is highest in the petiole, lowest in the mesophyll. Oxalic, citric, and the indefinite but small group of unknown acids are individually present in highest concentration in the mesophyll, lowest in the petiole. As a result of these two opposing concentration gradients, the concentration of total organic acidity is not far from constant in all parts of the leaf. These studies of rhubarb-leaf metabolism are being continued and promise to furnish interesting parallels as well as contrasts to tobacco-leaf metabolism.

The more strictly protein investigations of the laboratory have dealt for the most part with the behavior of tobacco-leaf protein *in situ* during hydrolysis with acids and with enzymes. It has been found that the nitrogen of the tobacco leaf which remains insoluble when the dried tissue is extracted exhaustively with hot alcohol and hot water is very largely protein. Nearly all of it can subsequently be brought into solution by the action of pepsin or of trypsin, and much of it also dissolves when the tissue is treated with hot alcoholic alkali. The various extracts, on hydrolysis with acid, yield proportions of amino and of ammonia nitrogen consistent with the view that they consist entirely of material of protein nature, and the solubility of the nitrogen when exposed to the action of typical proteolytic enzymes is strong evidence in favor of this view.

In connection with the nutrition investigations, descriptions of the methods long employed in this laboratory for the preparation of the important proteins, gliadin from wheat and zein from maize, have been published in response to many inquiries regarding these methods. New determinations of the basic amino acids of zein have also been made in an effort to correlate the chemical structure of this protein with the results of recently published determinations of its acid-binding capacity in alcohol solution. The new values confirm those obtained many years ago in this laboratory, and are in close agreement with the requirements of recent structure theory.

The following have served as assistants in the work: Alfred J. Wakeman, Ph.D.; Charles S. Leavenworth, Ph.B.; Rebecca B. Hubbell, Ph.D.; Luva Francis, secretary.

## PALÆONTOLOGY AND GEOLOGY

**Merriam, John C., and Associates.** *Continuation of palæontological researches.* (For previous reports see Year Books Nos. 20-35.)

In some particulars, the program of researches in 1936-1937 has necessarily widened the plans for study followed in recent years. Beginning with a series of special investigations looked upon as intrinsically important in the history of life and its geological background in America, the researches have extended to problems and to areas offering unusual possibility for elucidation of the principles under discussion.

With the exception of modest help to Dr. Horace G. Richards, of the New Jersey State Museum, in connection with studies of molluscan faunas distributed along the south Atlantic and Gulf coasts, there has been no special cooperation in the field of invertebrate palæontology. The work of Dr. Richards was aided because it has been especially useful in determination of geological sequences and geographic correlations of the first importance both in geology and palæontology of the southeastern part of the United States.

It may, however, be remarked that cooperation in the field of invertebrate palæontology has been possible on the part of the Institution through invitation to Dr. M. Lecompte, of Belgium, a student of marine invertebrates, who wished to know more of the factors conditioning life about a coral reef. At the Tortugas station in the Gulf of Mexico it was possible for Dr. Lecompte to study the reef under very favorable conditions and thus to secure data of much importance in any general consideration of reefs, recent or fossil.

The relation of researches under way to the field of plant fossils has been guided entirely by Dr. Ralph W. Chaney, Research Associate of the Institution and professor at the University of California. Dr. Chaney's studies on his expedition to China in the past year mark a significant epoch in the advance of palæobotany. Other investigators, aided and directed by Dr. Chaney, have made important contributions in many directions, all of which are fitted to the work of Dr. Chaney, and the investigations of Dr. Chaney are intimately related to those in other fields of palæontology and general geological history.

In accordance with the principle that it is essential to keep the studies of geological sequence in close relation to those concerned with the history and evolution of life, practically all of the investigations by the Institution have been planned with a view to making a contribution which can be utilized in both of these fields, although naturally the investigator places emphasis upon the subject of his special interest.

The most comprehensive group of investigations is that concerned with the story of the Grand Canyon, where, following the unexpected advances made in several important fields in recent years, it has seemed desirable to take up a number of problems which are of exceptional importance and unusually well illustrated at the Canyon. From the purely geological side,

the most important of these investigations is that carried on by Dr. Ian Campbell and Dr. John H. Maxson, of California Institute of Technology, on the Archean, or the oldest rocks of the Grand Canyon. Holding, as these rocks do, the earliest records of earth history, it has been essential to use every possible means to secure data which may give an understanding of what the rocks were originally, something of their origin, and whatever may be learned of their history. The section at the Canyon has proved to be very thick and quite complicated. It has, however, furnished much unexpected information, all of which tends to show that the Grand Canyon section is one of the most interesting in the world. The boat trip through the Canyon planned for this year has as its purpose investigation of great sections of the Archean which could be seen to advantage only from the river, and it is expected that the information from this six or seven weeks' trip will furnish new and significant data.

The investigations by Dr. N. E. A. Hinds, of the University of California, on the Algonkian rocks, the second series from the bottom of the Grand Canyon, have been carried on over a considerable period, until it has been possible to make acquaintance with most of the Grand Canyon section, as also with related rocks in surrounding or nearby areas. The fact that these rocks, in contrast to the Archean, show materials in considerable measure practically unchanged means that there is offered an opportunity to study the original conditions of deposition as also the subsequent history.

While it has been realized that the chances of obtaining traces of life in the Archean are almost infinitesimal, it has been natural to expect in unchanged sandstones and muds of the Algonkian, relics of whatever plants and animals might have been living in the region at that time. The calcareous deposits of the Algonkian, recognized as algæ some years ago by Dr. David White, have been found in large quantities in various forms by Dr. Hinds, and, in addition, he has secured an extraordinary trace of animal life in the imprint of a jellyfish which laid the tough mass of its jelly-like body upon a soft mud in which its imprint has been preserved to the present time.

Studies by Mr. Edwin McKee on the rocks above the Algonkian in the Grand Canyon have covered many portions of the section through a considerable length of the Canyon, involving correlation of deposits from a wide area. Special attention has been given to investigation of the Permian of the Grand Canyon with reference to its structure, its mode of formation, and its fauna. These investigations by Mr. McKee have furnished a valuable pattern for research on somewhat similar types of deposits in other portions of the section.

When the Grand Canyon studies covering the stratigraphic sequence, mode of deposition, relation to climatic conditions, and variation in basins of sedimentation have been completed, the way will have been opened for more intensive work on the origin, distribution, and evolution of faunas in this and related regions.



Investigation of the history and evolution of the great variety of types of vertebrate life in America, and particularly on the Pacific Coast, has been followed especially by Dr. Chester Stock with his associates at California Institute of Technology, with the cooperation of Dr. John P. Buwalda. Dr. Remington Kellogg, of the United States National Museum, cooperating with the Carnegie Institution, has continued his researches on history and evolution of the cetaceans.

The relation of palæontology and the geological sciences to study of the early history of man has included a number of types of investigation conducted during the past year, among the most important of which are those by Dr. H. de Terra, of the museum of the Academy of Natural Sciences of Philadelphia, in extension of the reports on his expedition to the region of northern India and the Himalaya. Dr. de Terra has now returned to Asia with the purpose of extending these studies to other parts of the continent in the expectation of cooperating with leading investigators of Asia in attempt to develop an adequate palæontological and geological correlation.

The investigations of Dr. George H. R. von Koenigswald, of Bandoeng, Java, described in another section of this report, have concerned especially the focusing of interest upon study of *Pithecanthropus* and upon the effort to secure additional material. Having examined the principal collections in Europe and having studied the extraordinary *Sinanthropus* material of China, Dr. von Koenigswald returned recently to Java, where he was fortunate in making immediate discoveries of material which seems to represent *Pithecanthropus*. If, as Dr. von Koenigswald believes, the specimens which he has received are *Pithecanthropus*, the lower jaw which he has obtained represents the first information on the mandible of the *Pithecanthropus* type, while a badly broken skull, which has now been pieced together, gives for the first time a large part of the structure of the *Pithecanthropus* cranium. Dr. von Koenigswald's conclusions are that *Pithecanthropus*, which has long been considered the most primitive of human types, is actually the most primitive fossil now known.

Investigations on the problem of early man in America have comprised many types of studies, some of which are purely geological, some geological-climatic, and some geological-palæontological. The interesting cooperation of Dr. Ernst Antevs with investigators working with Dr. Edgar B. Howard, of the University of Pennsylvania, made it possible to re-study a number of important sites and to examine new sites presenting material of exceptional interest. One of the localities most recently discovered which presents an important series of problems is that at Catlow Cave, in eastern Oregon, where the discovery was made and the excavations carried out by Dr. L. S. Cressman, of the University of Oregon. These investigations have seemed to lead, as in the case of many studies of older remains in this country, in the direction of a conclusion that man in America is more ancient than has been assumed; it remains to be shown, however, how far his history extends into the Pleistocene.

*Studies on the Climate in Relation to Early Man in the Southwest, by  
Ernst Antevs*

The studies on the pluvial and postpluvial climates of the Southwest have been continued, and the results applied to the dating of records of early man and to the study of his living conditions.

The Cochise culture, in the study of which the writer has been privileged to collaborate with Dr. Emil W. Haury and Mr. E. B. Sayles, of Gila Pueblo, who first recognized its significance, has been referred, on the basis of geological occurrence, fauna, and flora, to the last pluvial period. The type locality is near the Double Adobe School northwest of Douglas in southeastern Arizona.

On the beaches of pluvial Lakes Cloverdale in the southwestern corner of New Mexico and Cochise in southeastern Arizona the writer has found miscellaneous flaked stone implements, perhaps belonging to the Cochise culture, although their contemporaneity with the pluvial lakes has yet to be established. The artifacts on Lake Cochise include choppers, various types of scrapers, knives, and miscellaneous projectile points, artifacts which show at least a superficial resemblance to those found by Mr. and Mrs. William H. Campbell and Mr. Charles Amsden on the beaches of pluvial Lake Mohave in southeastern California.<sup>1</sup>

The arroyo cutting, or trenching of the stream beds, that has been going on in the Southwest for some 50 years has exposed evidence of successive deposition and erosion during the past. Arroyo cutting occurs when the runoff is excessive and too rapid because of a deficient vegetation cover, a condition caused in modern time by overgrazing or the like, but in the past a result of drought. Past stages of erosion and filling thus record dry and moist ages. In several cases embedded potsherds make possible a fairly accurate dating of the climatic fluctuations. Sherds have been identified and dated by staff members of Gila Pueblo and by Mr. Lyndon L. Hargrave, of the Museum of Northern Arizona, Flagstaff.

River terraces and their conditions of formation have also been studied for the light they may shed on past climatic fluctuations.

*The Age of the "Minnesota Man," by Ernst Antevs*

A field conference at the "Minnesota Man" site three miles north of Pelican Rapids, Minnesota, on June 21 and 22, 1937, was attended by Dr. A. E. Jenks, Dr. Kirk Bryan, Dr. Paul MacClintock, Father Henry Retzek, Mr. Franklin B. Hanley, Mr. Ernest Berg, and the writer. All agreed that the varved glacial silt in the road cut about the site was disturbed, a condition heretofore denied.<sup>2</sup> Mr. Hanley, Mr. Berg, and the writer studied the

<sup>1</sup> Elizabeth and W. H. Campbell, Ernst Antevs, Charles Amsden, J. A. Barbieri, and F. D. Bode, The archeology of Pleistocene Lake Mohave. Southwest Museum Papers, No. 11, Los Angeles, June 1937.

<sup>2</sup> Kirk Bryan, Minnesota man—a discussion of the site. *Science*, vol. 82, 170-171 (Aug. 23, 1935).

*Idem*, Ancient man in America. Review of book cited in note on next page. *Geogr. Rev.*, July 1937, pp. 507-509. See p. 508.

G. A. Thiel, The Pleistocene geology of the Prairie Lake region. Pp. 17-33 in book cited in note on next page. See pp. 23, 25.

glacial geology of the region for two more days. The following views are those of the writer.

Since the road cut was made in 1929, the banks are now naturally slumped and partly overgrown, but the narrow vertical exposure which we made where the cut is highest, or 90 feet northeast of the site,<sup>1</sup> showed the following beds:

At top, 12 inches soil, A-horizon.

24 inches soil, B-horizon.

20 inches soil, C-horizon.

40 inches yellowish, sandy silt and white, fine sand. Bed disturbed. Small lumps of white sand in the silt.

8 inches tough, yellow-brown, sandy silt.

28 inches silty, yellow sand, 5 or 6 varves, an ice-lake deposit. Winter layers disturbed.

8 inches yellow-brown silt and fine sand.

4 inches bluish clay, probably 4 varves. Clay layer curled and pinched out toward the south.

21 inches yellow-brown silt and fine sand.

4 feet silt, 12 varves. Summer layers of yellow-brown silt, winter layers of gray-blue clay. All winter layers display slickensides and silt kneaded into the winter clay—disturbed through sliding.

Gray-brown sand at 7.5 feet below the level of the road surface.

Comments which the writer made in a letter of January 18, 1934, to Dr. George A. Thiel, based on large and clear pictures which the latter had kindly sent, give a better idea of the nature of the disturbances:

"Also in picture No. 1 the silt is disturbed all through. Not one varve has escaped, is of original thickness. At right and center bottom a winter layer dips some 30°.

"Picture No. 3. Near upper left corner: deposit looks massive.

"Picture No. 5. Halfway up: a glide zone across the picture.

"The disturbances can be due to various causes. (I touch upon them in 'The recession of the last ice sheet in New England,' Amer. Geogr. Soc. Research Ser. No. 11, 1922, p. 72.) A possible cause of special interest in this case is gliding, since the girl might have been buried by a landslide a long time after the deposition of the clay."

The site of the skeleton being 4 feet beneath the center of the paved highway, the nearest place where the beds can now be observed is the road bank 50 feet to the east. The beds are here faulted and squeezed, and lumps of white sand are kneaded into a bed of brown silt.

The skeleton was found by a road crew in June 1931 after a road grader, hauled by a tractor, had cut into and through the highway surface to remove a frost boil and then had exposed a shining clamshell lying just above the skull (Jenks, pp. 7, 10). The road men, who removed the skeleton, testify that the overlying silt was undisturbed (Jenks, pp. 13, 14, 181). Actually, however, it would have been a difficult matter for experts to determine whether or not the silt, largely removed, was undisturbed before it was heaved by frost, pressed by the weight of the tractor, and smeared

<sup>1</sup> A. E. Jenks, *Pleistocene man in Minnesota, a fossil Homo sapiens*. University of Minnesota Press, 1936. See pp. 8, 30.



and crumpled by the blade of the grader. The disturbances in the walls of the road cut are results of slide, creep, and slump, and evidently cannot terminate within the knoll, but must extend to its edge, i.e. must have extended over the site of the skeleton. Therefore, if the overlying material really was glacial varved silt, the road men failed to notice slide disturbances in the silt; it follows that they can have overlooked disturbances resulting from burial of the girl. Consequently there is no valid observation to the effect that the girl was embedded in varved silt during its deposition in the late glacial ice lake. As discussed below, the overlying material was perhaps not glacial silt, but postglacial wash.

Since the skeleton occurred at a depth of 10 feet, the girl may not have been buried by her people from the recent ground surface. She can have been buried, however, at a time when the surface was lower; and the thick overburden can be a result of downwash of silt and soil over the grave by rains, or of sliding of a silt bed over the grave, as originally held by the writer.<sup>1</sup>

Accumulation of the excessive overburden by wash can be inferred from cross-section profiles of the knoll measured by the road surveyors (Jenks, p. 11), and from a rather sudden southward increase in the thickness of the soil and the beds overlying the varved silt in the road cut 50 feet east, 25 feet south of the site. The profiles show that there was a very shallow gully over the site. This gully, which started near the crest, or less than 100 feet to the north, was removed and masked when the road cut was made through the knoll and the roadbed built up over its middle and lower course. There are similar gullies close by. The gully can once have been some 5 to 10 feet deep over the site and later have become almost filled by wash.

The sliding and slumping of the silt can have taken place on one or several occasions. It can have been caused by: (a) melting of the ice blocks between which the varved silt seems to have been deposited—one ice block was only 200 feet south of the site; or (b) oversteepening of the silt knoll by wave action of glacial Lake Pelican or of its postglacial (?) successor, which is recorded by beaches standing some 12 feet above the modern adjacent Prairie Lake. The slides, of which the disturbances of the varved silt are a consequence, may thus have occurred shortly after the deposition of the silt and later in the late glacial age, and in part perhaps during the postglacial age.

The occurrence of the skeleton can thus be explained in the following ways: (a) the girl can have drowned in glacial Lake Pelican and become covered by the settling silt, as held by Dr. Jenks and Dr. Thiel; (b) the body can have been buried by her people, and the overburden later increased by rain wash or, less likely, by slide; or (c) the girl can have died in a gully, and the entire overburden washed or slid over the body. Since the first possibility is not made probable by any evidence, one of the other two may represent the actual events. But there are no geological data bearing directly on the girl's age.

<sup>1</sup> Ernst Antevs, The spread of aboriginal man to North America. *Geogr. Rev.*, April 1935, pp. 302-309. See p. 305.



The animals represented by tools, ornaments, and "medicine" found with the skeleton furnish no reliable information on the climate of the region during the girl's life, for, since *Busycon perversa*, a marine snail living, according to information received from Dr. Horace G. Richards, from Cape Hatteras to, and probably beyond, the Mexican boundary, had been traded 1100 miles, other forms can have been traded short distances. However, the majority were probably native to the region. The animals are, besides *Busycon* (Jenks, pp. 161-169): American wapiti or elk (*Cervus canadensis*); eastern timber wolf (*Canis lupus* or *C. lycaon*); perhaps muskrat (*Ondatra zibethicus*); common loon (*Gavia immer*); a turtle, perhaps *Chrysemus belli*, or less likely, *Emys blandingii*; and "mucket" clam (*Lampsilis siliquidea*).

At the arrival of the white man, the wapiti ranged from southern New Mexico northward to Fort Nelson River in northern British Columbia, the timber wolf from the mountains about the Valley of Mexico as far north as land extends, and the muskrat from the Gulf of Mexico northward to the limit of trees, and locally into the Barren Grounds.<sup>1</sup> The loon breeds from northern Illinois and Minnesota to the Arctic Ocean. The painted turtle (*Chrysemus*) ranges from Texas into southern Canada, and is recorded as far north as Lake Winnipeg, and Blanding's turtle is distributed from Nebraska and southeastern (?) Minnesota eastward.<sup>2</sup> The mucket clam lives from the Gulf of Mexico at least as far north as Great Slave Lake. The absence of distinctly arctic forms is noteworthy. Thus the animals suggest, if anything, that the climatic conditions of the region during the girl's time resembled those now prevailing.

The shell of *Busycon perversa*, traded from the distant Gulf Coast, probably holds the best possibility for dating the skeleton. This snail, according to information received from Dr. Thorne Deuel, of the University of Chicago, occurs in Illinois and Ohio in Indian mounds of the Hopewellian phase and in the middle phase of the Mississippi Pattern, i.e. roughly speaking from A.D. 1000 to 1500.

Thus the few and inconclusive clues bearing on the age of the skeleton suggest that it is of postglacial, pre-Columbian or early Columbian age. No conditions speak for, but some against, its deriving from the late glacial, to which, obviously, it should be attributed only on the basis of irrefutable evidence.

#### *Researches of J. P. Buwalda*

The mapping and study of the faults along the south base of the San Gabriel Mountains in the Pasadena region of southern California was considerably extended during the past year. The fault zone, vertical displacements along which have given the range its abrupt and bold face and its

<sup>1</sup> E. W. Nelson, The larger North American mammals. Nat. Geogr. Mag., November 1916, pp. 385-472. See pp. 421, 453.

*Idem*, Smaller mammals of North America. *Ibid.*, November 1918, pp. 371-493. See p. 411.

Dr. Rudolph M. Anderson, of the National Museum of Canada, personal information.

<sup>2</sup> Leonhard Stejneger and Thomas Barbour, A check list of North American amphibians and reptiles. 3d ed., Harvard University Press, 1933. See pp. 142, 146.

Dr. Stejneger, personal information.

height above the San Gabriel Valley to the south, is very complex in character, both as to surface pattern and as to three-dimensional relations. It has heretofore been held that the faulting is reverse in character and that hence the south front of the range is being thrust southward over the San Gabriel Valley block, and away from the San Andreas fault. It is true that many of the individual faults in the zone of displacement are of the reverse type, but further mapping has demonstrated that some of the fractures are certainly normal, dip to the south away from the range, and imply lengthening rather than shortening in a north-south direction.

Study of this fault zone is definitely confirming the view that the San Gabriel Mountains are still rising. Epicenters of small earthquakes have been located along this fracture belt from time to time by members of the staff of the Pasadena Seismological Laboratory, giving rise to the belief that the ultimate displacement and uplift along the zone had not been completed. Corroborating this view are the numerous fresh scarplets found in the course of the present study along the base of the range, indicating repeated vertical dislocations of the present landscape. Accordant evidence consists of Quaternary gravels faulted down against granite along some of the faults, also implying vertical fault movements in relatively recent geologic time. The magnitude of the total displacement along the zone, some thousands of feet, almost certainly signifies that strong earthquakes originated in this fracture belt repeatedly in the past, at the times of recurrent slip, and although this zone is not one of the remarkable strike-slip faults of California to which most of the strong shocks of the historic period have been attributed, it can scarcely be ruled out as a potential source of destructive earthquakes in the future.

#### *Researches of Remington Kellogg*

Aside from continuing studies based on Recent material in the U. S. National Museum, supplemented during May and June by an examination of the cetacean collections of the British Museum (Natural History) and the Museum of the Royal College of Surgeons in London, special attention was given to the cetotheres, an extinct group related to the Recent whale-bone whales. A careful survey is being made of all available information relating to the fossil cetotheres described by Professor E. D. Cope. Many of these have never been figured and a few specimens have not as yet been located. Most of the genera and species described by Cope are based on portions of jaws, vertebræ, or incomplete crania. For some of these neither the geological formation nor the locality is known. It is hoped that the types of all these cetotheres can be compared directly with recently collected material from the Calvert Miocene formation of Maryland and Virginia. The preservation of these Calvert cetotheres is such that the crania frequently can be disarticulated, so that the telescoping of the various cranial elements can be studied in considerable detail. A thorough knowledge of the morphology of these cetaceans is necessary to a proper understanding of the general process of telescoping. To obtain this information it is necessary to have adequate material for study and comparison. Fortunately through the cooperation of Mr. Marc Lagen, of the American Pacific Whaling Com-

pany, the U. S. National Museum has received recently the heads of a number of fetuses of whalebone whales. This material will furnish detailed data concerning some of the early growth stages of the mysticete skull.

In the course of the past year, Sydney Prentice has prepared a number of illustrations for the Calvert cetotheres.

*Researches on the Recording and Classifying of Bedding Patterns in the Colorado River Delta and Other Modern Deposits, by Edwin D. McKee*

Detailed studies of Paleozoic strata in the Grand Canyon region have demonstrated to the writer the need for specific data pertaining to the significance of various types of bedding. Thus the recording and classification of comparable types in areas of modern deposition represent fields of investigation which, although virtually untouched, are very important in the proper interpretation of many sedimentary formations. Accordingly a program of systematic study has been initiated with work centering at present on the Colorado River delta in Mexico and on certain sand-dune areas in Arizona.

Considerable time and thought have been spent during the early stages of this study in developing methods and technique for recording types of bedding. Experiments have been made on slicing and channeling recent sedimentary deposits to obtain cross sections, on etching out laminations by blowers, and on photographing and tracing lamination patterns. These methods have been applied with success on the Colorado River delta and on certain local sand dunes. Furthermore, the basic elements for a system of classifying types of bedding are becoming apparent with the accumulation of data obtained by making three-dimension records.

Explanation of the origin of several types of deposits found in certain Grand Canyon Paleozoic formations has already become apparent through the analysis of lamination patterns; thus the value of the present study is evident. A preliminary publication on these investigations is being prepared.

*Researches on Paleozoic Stratigraphy in Western Grand Canyon, by Edwin D. McKee*

This program of stratigraphic studies was started during the winter of 1936-1937 for the purpose of determining the character and extent of changes in the Paleozoic formations of Grand Canyon when traced westward from the well-known Bright Angel section. Acting as field assistant in these studies was Mr. Russell Wheeler, now with the Shell Oil Company.

The program of field investigation has consisted of trips into Toroweap, Parashant, Diamond Creek, and Quartermaster Canyons and to Emory Falls in Grand Canyon; also to Iceberg Canyon immediately to the west. Travel, which was by automobile, horse, foot, and boat, was difficult, and weather conditions for the most part were unfavorable; however, results obtained from the work were gratifying. Detailed sections were measured at each of the localities mentioned and extensive fossil collections were made.



While comparative data on the various sections are yet to be worked out and most of the fossils still require identification, several features, significant in the history of the region, may be reported at this time.

1. The Lower Cambrian epoch is represented in Grand Canyon by strata (*Olenellus* beds) which were found at five distinct localities and which merge eastward into the upper part of the Tapeats sandstone.

2. The Devonian period is represented in the western part of Grand Canyon by a considerable thickness of limestone beds which show at their base a surface of much relief developed on the underlying Cambrian rocks. The Devonian strata consist of three principal types: (1) lavender, sugary, irregularly bedded limestone; (2) white or pale gray, finely laminated, thin-bedded, hard, dense limestone; and (3) dark gray, crystalline, massive limestone which weathers to a sandy, olive-gray surface. The total thickness at Diamond Creek is 359 feet; at Quartermaster Canyon, 25 miles to the northwest, 1156 feet; and at Iceberg Canyon, the same distance still farther to the northwest, 1340 feet. Field evidence indicates that the small amount and local distribution of Devonian beds in eastern Grand Canyon is due largely to greater erosion in that area rather than to lack of deposition. Fossils were found scarce and poorly preserved in all sections examined, but probably enough were collected to throw light on the age of the deposits.

3. The Mississippian Redwall was found to increase in thickness westward and is represented in the area studied by two massive units rather than by one as in eastern Grand Canyon. The lower and thicker unit is equivalent to the Redwall as recognized in the Bright Angel section and is probably of Madison age. The age of the upper unit has not yet been determined, but several collections of fossils from it should throw light on the problem.

4. The limestones at the base of the Supai formation increase westward in thickness and prominence. Their age, which is either Pennsylvanian or early Permian, has not yet been ascertained, but fossil material collected from several localities and horizons should indicate the answer. From Toroweap Valley westward these limestones represent stages in cyclic sedimentation of an interesting type. A complete cycle is as follows: (1) red beds; (2) cross-laminated, sandy limestones; (3) flat-bedded, sandy limestones; (4) crystalline, fossiliferous limestones; (5) flat-bedded, sandy limestones; (6) cross-laminated, sandy limestones; (7) red beds.

5. The Hermit shale thickens rapidly westward. Thus it is apparent that most of the red-bed deposits found under the Kaibab limestone in western Arizona and commonly referred to the Supai formation are actually Hermit shale. In Parashant Canyon a collection of plants was obtained from the Hermit containing *Gigantopteris americana*, as well as several well-known Hermit species.

*Researches on Middle Permian Strata of Grand Canyon National Park,*  
by Edwin D. McKee

During the past season studies of the Kaibab and (proposed) Toroweap formations that have been under way since 1933 were brought to completion. The principal work in this connection during the year consisted of examina-



tion of sections in southwestern Utah and southern Nevada, systematic description of the brachiopod fauna, and the preparation of a monograph covering the results of the entire investigation.

The following summary covers the most important discoveries and the outstanding conclusions reached as a result of these researches:

The uppermost Permian strata over most of northern Arizona, southern Utah, and southern Nevada—formerly known as the Aubrey limestone and later as the Kaibab limestone—are found to consist in typical exposure of two massive limestone members, above and below each of which are units composed of red beds, gypsum, and impure, thin-bedded limestones. Since these two sequences of sediments represent separate advances and retreats of the sea over a wide area, since the massive limestones within them contain distinctive marine faunas, and since evidence of a widespread, though not great, unconformity has been found at the top of the middle red-bed member, it seems desirable to consider each series as representing a formation.

In view of the complex conditions cited above it is proposed that the name Kaibab be restricted to the upper massive limestone together with associated members above and below and that these be termed Kaibab formation rather than Kaibab limestone in order to convey a true picture of the variety of lithology represented. For the three members below the unconformity, which likewise represent deposits of an advancing and retreating sea, the name Toroweap formation is suggested. It is taken from Toroweap Valley, Arizona, where the type section of the formation is well exposed.

Detailed studies of the lateral variations found in each of the members of the Toroweap and Kaibab formations have demonstrated the desirability of recognizing facies based on the lithology and faunas in each. Such facies have been designated by numbers.

In the massive limestone member of the Toroweap formation lateral changes from west to east or from the open sea toward the shore consist of a decrease in thickness, an increase in both elastic sand and magnesium content, and a replacement of the molluscoid fauna by one of mollusks. In the Kaibab formation the massive limestone member shows corresponding variation in fauna and composition from west to east, but differs in other respects. It extends considerably farther east, especially on the Mogollon Plateau, and maintains a fairly uniform thickness over most of the region of exposure. Several more facies are recognized in it than in the Toroweap, including one containing bedded cherts and another composed entirely of elastic sand.

The nonmarine members of the Toroweap and Kaibab formations—formed before and following the advances of the sea—show, in general, the following lithologic types from west to east: (1) structureless red beds (mostly mud and silt) with gypsum deposits and thin-bedded, magnesian limestones; (2) structureless red beds (silt and sand); (3) light-colored sandstones much cross-laminated on small scale (water types); (4) light-colored sandstones cross-laminated on large scale (æolian type). Not all of the red-bed members today show the light-colored sandstone equivalents to the east, but if the extensions of these deposits were still observable, it seems probable that a type of gradation comparable with that established for other members would appear.

Evidence regarding the general environment of the region during the time of Toroweap and Kaibab deposition leads to the conclusions that the climate was semiarid or arid, that the sea was very shallow, and that the surrounding terrain was flat and featureless over a vast area. It seems reasonably certain that a relative movement of the sea level of only a few feet was sufficient to allow inundation or retreat of the sea over many miles.

Detailed studies of the various types of sediments included in the Toroweap and Kaibab formations have led to the following conclusions:

1. The relatively pure, coarsely crystalline limestones were formed by a secondary growth of calcareous deposits laid down in the open seas, presumably by organic processes, at considerable distances from shore.

2. The dolomitic limestones were formed in near-shore and lagoonal environments, with dolomitization occurring as a secondary process among unconsolidated sediments.

3. Certain thin-bedded, fine-, uniform-grained limestones occurring as transition stages between red beds and marine limestones and also in association with gypsum deposits are interpreted as chemical precipitates.

4. The gypsum deposits are the product of evaporation in playas or land-locked embayments.

5. The red beds derived their color at the place of origin and retained it wherever sufficient mud and silt remained in the deposits that were spread out in the arid or semiarid basins of accumulation.

6. The numerous local "breccias" throughout the red-bed series are considered to be intraformational conglomerates.

7. The cherts are thought to be largely a phenomenon of the sea floor, developed by pene-contemporaneous replacement. The silica is believed to have been supplied to the sea by rivers and, depending on local conditions, was either laid down in beds or developed into concretionary forms around sponges and other nuclei.

The marine fauna of the Toroweap formation is not yet well enough known for critical analysis. The fauna of the Kaibab is better known, however, and most of its brachiopods have been described by the writer. On the basis of these forms, it seems quite definite that the Kaibab is to be correlated with the upper part of the Leonard formation of Texas, hence is of Middle Permian age. Furthermore, the Kaibab is believed to be the equivalent of the San Andres limestone of New Mexico, the Chiricahua of southern Arizona, and probably also the Phosphoria of Utah, Idaho, and Wyoming, although the latter undoubtedly represents an unusual environment with most of its fossils highly specialized in character. In brief, it is believed that the Kaibab was deposited in part of a great Middle Permian seaway which extended from west Texas westward along the Mexican border to western Arizona, thence northward through the Great Basin region into Canada and Alaska.

#### *Researches of Chester Stock*

The past year has seen continuation, along a broad front, of the palæontological investigations which relate particularly to the history of the mammalian group for the Tertiary and Quaternary of western North

America. Emphasis has been placed in large measure upon faunal studies, although considerable attention has been given to phylogenetic problems. During the past year the following papers have been published as articles I to III, Carnegie Institution Publication No. 487:

Wilson, R. W. New middle Pliocene rodent and lagomorph faunas from Oregon and California.

Wilson, R. W. Pliocene rodents of western North America.

Schultz, J. R. A late Cenozoic vertebrate fauna from the Coso Mountains, Inyo County, California.

In addition to the above there has now been completed and submitted to the Institution for publication an exhaustive study by John R. Schultz of the mammalian fauna from the Pleistocene asphalt seeps of McKittrick, California. This paper marks an important step in our comprehension of the development and distribution of the late Pleistocene life of western North America. It presents the picture of a significant life stage from another asphalt deposit, second only in the importance of its animal record to that of Rancho La Brea.

Two reports have been completed and await submittal to the Institution for publication. One of these, by Dr. Hildegard Howard, of the Los Angeles Museum, comprises a detailed study of the Rancho La Brea caracara, one of the unusual types of raptorial birds occurring in the Pleistocene asphalt. The second report is by Dr. Edwin H. Colbert and concerns itself with the Pliocene peccaries from western North America, now in the collections of the California Institute of Technology. The types of peccaries known from the Kern River, Thousand Creek, Rome, Rattlesnake middle Pliocene, and Coso upper Pliocene are described, and those from the middle Pliocene horizons are for the first time satisfactorily determined. Unusually well-preserved remains of the characteristic *Hipparion* species from the Thousand Creek beds of northwestern Nevada have been under study by Chester Stock and the report on this material is nearly complete.

Through the courtesy of the Regional Officer, Branch of Planning and State Co-operation, National Park Service, specimens of dung of the extinct ground sloth *Nothrotherium* were obtained from the newly discovered cave sites in the lower Grand Canyon, mentioned in Carnegie Institution Year Book No. 35, page 320. This material is being analyzed by Mr. J. D. Laudermilk with the assistance of Professor Munz, of Pomona College, Claremont, California. Identification of the plant remains in the dung and a comparison of this flora with that growing in the vicinity of the caves at the present time throws interesting light on the succession of plant life and on the changing climatic conditions of this section of the Southwest during late Quaternary time. Another important aspect of this investigation is the comparison of the new materials from the lower Grand Canyon caves with that described several years ago from Gypsum Cave. Mr. Laudermilk's report will be submitted shortly for publication.

A further study of the mammalian fauna obtained in Smith Creek Cave, Nevada, is under way. Among special features of this investigation may be mentioned particularly the recognition of a mountain goat distinct in structural characters and in size from the living mountain goat and possess-



ing a distribution well to the south of that of the living species. This animal was described by Chester Stock in the *Bulletin of the Southern California Academy of Sciences* (vol. 35, 149-153, pls. 34-35, 1936). In order to determine the relationship of the mammalian forms preserved in the deposits of Smith Creek Cave to types living in this region of the Snake Range at the present time, and thereby to evaluate the amount of faunal change that has taken place since the cavern accumulation occurred, an arrangement was made with the Museum of Vertebrate Zoology, University of California, to make a biological survey of the area in which the cave is located. This survey, which involved the collecting of Recent mammals, was satisfactorily completed during the month of June 1937 by a field party from the Museum. Further comparison of the cave material awaits the preparation of the specimens collected in the field.

At the request of Mr. A. E. Henning, Chief, Division of Parks for the State of California, examination was made by Arthur Drescher and Dr. John R. Schultz of caves occurring in Fremont Peak State Park near San Juan Bautista, California. While the exploratory examination revealed no evidence of palæontological or archæological materials, opportunity was taken in the field to discuss the possibility of development of these cave sites as added attractions for visitors to Fremont State Park.

**Campbell, Ian, and John H. Maxson**, California Institute of Technology, Pasadena, California. *Geological studies of the Archean rocks at Grand Canyon*. (For previous reports see Year Books Nos. 33-35.)

Delay of the projected boat expedition through Grand Canyon, due to Dr. Maxson's absence on foreign work, curtailed field explorations in this region during the year just past. Some field work was continued in the Lake Mead area, especially in the Lower Granite Gorge, which is becoming increasingly accessible as the water back of Boulder Dam continues to rise. Petrographic studies, on material collected in previous field seasons, have been continued in the laboratories of the California Institute of Technology.

A feature which draws immediate attention in the Lake Mead area is the sudden change from the flat-lying beds of the Colorado plateaus, which occur as far west as Grand Wash, to the disturbed and complex structures to the west, more characteristic of the Basin and Range province. A possible explanation for this feature may be found in the character of the basement rocks. There is strong evidence to indicate, in the Grand Canyon region, that the structure of the Archean rocks has considerably influenced later structures. The strike of many of the prominent faults, for example, coincides with the strike of the schistosity in the Vishnu, or with the strike of prominent joints in the granites. In the Lower Granite Gorge, the basement rock is a relatively massive and homogeneous granite, comparatively free from inclusions or admixture with schist, and not carrying any noteworthy jointing systems. To the west, at about the line where change in structure of the Paleozoic formations becomes apparent, this massive granite gives way to an area of more complex rocks, perhaps to be classed as migmatites, and involving thin to thick septa of schist intercalated with gneisses and gneissoid



granite. Where major tectonic forces are involved, it is to be expected that such a terrane will suffer greater distortion than one underlain by massive granite, and in this may be found at least partial explanation of the structure in upper Lake Mead.

Petrographic studies, supplementing earlier field work, have shown that the pegmatites of the Grand Canyon area are mineralogically simple, but genetically complex. Some of these bodies have formed by replacement processes akin to the "granitization" phenomena now being increasingly recognized as a mode of formation of certain granites. "Pegmatization" has been proposed as a name for this process when operating to form pegmatites. Other pegmatites appear to have formed because of feldspathization of quartz bodies. These occurrences are particularly interesting because the feldspar is microcline, hitherto not generally recognized as a replacement feldspar.

Plans for the boat expedition for the fall of 1937 have been matured, and the start from Lee's Ferry will be made early in October. Knowledge of the Archean section will be greatly extended by this expedition and many gaps in the Archean history of the region should be filled in.

It is a pleasure to acknowledge the cooperation, in certain phases of this work, of Dr. J. Volney Lewis, Mr. E. D. McKee, and Mr. E. T. Schenk, all of the National Park Service.

de Terra, H., Museum of the Academy of Natural Sciences of Philadelphia, Philadelphia, Pennsylvania. *Studies of geology, palæontology, and archæology relating to the origin of man as it may be recorded in the Himalayan region of Asia.* (For previous reports see Year Books Nos. 34, 35.)

The studies on the results of the Yale-Cambridge India Expedition of 1935, to which the Carnegie Institution of Washington contributed funds by special grant from the Carnegie Corporation of New York, progressed according to program. It had been planned to finish the most essential part of this work by the fall of this year, and most of the results had actually been completed by that time.

Professor William K. Gregory and Dr. M. Hellman, to whom the study on the fossil anthropoid material had been intrusted, have completed their manuscript for publication.

The geological and archæological data on the Quaternary of India have been compiled in form of a larger report which bears the title "The Ice Age in India and associated human cultures." Its first part deals with "The Ice Age in southwestern Kashmir," while the second treats of "The Pleistocene in northwestern and peninsular India." Under the former title Mr. Paterson and Dr. de Terra have described their observations and interpretations concerning the Quaternary in the Himalayas, and an analysis is given of the climatic and orogenic cycles which characterize the geological history of that region in a unique and significant fashion. In view of the unfamiliar and little-known nature of this area, the authors have presented a great many geological sections and maps so that the reader may himself be able to judge the evidence for a fourfold glaciation in

the Himalayan highlands. Especial emphasis is laid upon the effects of repeated mountain uplifts on the glacial cycle and on the redistribution of plant life due to vertical shifting of plant zones. It was found, as had previously been reported, that the second ice advance could not have been so extensive in the sub-Himalayan hills if it had not been preceded by strong uplift at the close of the first interglacial period. The geologic data from southern Kashmir are then compared with others gained on previous journeys to Indian Tibet, and this leads to a general review of the Quaternary in the Himalayan highlands.

In this manner the Ice Age history of Kashmir with its clearly defined climatic and tectonic cycles is used as a standard measure for the geologic history of early man in India. This is dealt with in the second part of the report, which pertains especially to the neighboring Potwar region in the Punjab, where most of the prehistoric records were found. Following a brief discussion of the late Siwalik geology, a detailed account of all sites and associated geologic sections is given. A special chapter written by T. T. Paterson is devoted to the "Prehistory of the Punjab," in which the Stone Age industries of northwest India are typologically classified and defined. One of the major results commanding a more general interest is the observation that with exception of the Abbevillian and Acheulian no industries were encountered which bear resemblance to the middle or late palæolithic cultures of Europe. Most probably this indicates an independent evolution of human prehistory in India dating from the time of the third glaciation. A detailed account may be found also of the Pleistocene in the Narbada Valley of central India, and of the culture-bearing sequence in the Madras region of southern India. A concluding chapter describes the proto-neolithic sites of Rohri and Sukkur in Upper Sind, where a great number of tools were found in regular factory sites of pre-Metal Age, reminiscent of the late Tumbien of Africa.

Apart from the completion of this manuscript, the writer was occupied with work connected with his position as associate curator of geology in the Museum of the Academy of Natural Sciences at Philadelphia. As a member of the organization committee for the "International Symposium on Early Man" he helped to draft plans for the sessions, and assisted in the correspondence with foreign scholars and in the choice of addresses to be delivered during the congress.

Under the chairmanship of Dr. John C. Merriam, the congress opened on March 17 and lasted until March 20, during which time the problems of human origins were briefly discussed by a great variety of scholars working in allied fields of archæology, geology, palæontology, botany, and human anatomy. One of the direct results of one of the round table discussions on early man in Asia was the drafting of a plan by the writer concerning an expedition to southeastern Asia.

This new study project was jointly discussed with Dr. Teilhard de Chardin and Dr. Gordon T. Bowles, of Harvard University, who very kindly furnished important information on certain discoveries of Stone Age tools recently made in Upper Burma. The intermediate position which Burma holds between India and Java, as regards both its geology and its palæon-

tology, makes it a most promising research field which is closely linked with others in China and Malaya. The expedition plan calls for a four-month survey of late Cenozoic formations in Upper Burma and for archaeological excavations in culture-bearing terraces of the Irrawaddy and Sittang Valleys. The results gained from this work will be correlated with data recently obtained in India and then supplemented by a study tour to Java. Here several field trips will be made under the guidance of Dr. G. H. R. von Koenigswald, who at present is engaged in similar studies under the auspices of the Carnegie Institution. The return route to the United States will be by way of the Philippines, where possibilities for Quaternary geology will be explored.

As co-sponsors of the expedition appear Harvard University and the American Philosophical Society, the former sending Dr. H. L. Movius as archaeologist to Burma for a detailed investigation of the palæolithic history of early man. Dr. Teilhard de Chardin is scheduled to join the writer in the latter part of November in Upper Burma. The expedition leader and Dr. Movius sailed from New York at the beginning of October and will start field work during the second half of the month of November.

**Hinds, Norman E. A.**, University of California, Berkeley, California. *Researches on Algonkian formations*. (For previous reports see Year Books Nos. 34, 35.)

During the summer of 1937, the writer continued field study of Algonkian and associated pre-Cambrian strata in southeastern Arizona and southern New Mexico. Special attention was given to the nature and distribution of strata belonging to the Algonkian (Beltian) Apache group and to a search for fossils in its various members. Brief time was spent in securing more information regarding certain relations of the Mazatzal quartzite, a pre-Beltian series which has been classed by the writer as Uncompahgran. Laboratory study of the Grand Canyon Algonkian, central project of this research, was carried on during the year and the report on this sequence is nearing completion.

The Apache basin of deposition was limited on the north by the Mazatzal Mountains, a northeast-southwest trending barrier which had been created by the folding of the Mazatzal quartzite. These mountains separated the Apache basin from the Grand Canyon basin to the north, where more than 13,000 feet of Beltian strata were deposited. For about 130 miles south of the Mazatzal barrier, exposures of Apache strata are found in many of the basin ranges. Positively identified beds are known as far south as the Santa Catalina Mountains, about 25 miles northeast of Tucson, and certain metamorphosed strata in the Little Dragoon Mountains, 30 miles still farther to the south, also may belong to this group. Since this area is being surveyed by a graduate student of the University of Arizona, no attempt was made to settle this question which he suggested; metamorphism by Cretaceous granite makes necessary a detailed survey of the sedimentary sequence. Long stretches of the contact between the Cambrian and pre-Cambrian were examined in the Big Dragoon, Dos Cabezas, Chiricahua, and Huachuca Mountains and in the Clifton-Morenci district of



southern Arizona, but no remnants of the Apache beds were found, nor have any been reported by geologists who have worked in various parts of these areas. So far as the writer has seen, no exposures are present in southern New Mexico. In an east-west direction, Apache beds are found at various places from the Natanes Plateau to the Vekol Mountains, a distance of more than 90 miles. The outlier in the Vekol Mountains is about 60 miles distant from the nearest known Apache beds to the east, but with little question belongs to the Apache group, as Darton<sup>1</sup> stated.

The Apache basin probably was not long-lived, for none of the remnants of its deposits greatly exceed 1000 feet in thickness, and there is little evidence that particularly deep erosion took place before the invasion of the Middle Cambrian sea. Sedimentation appears to have been terminated by moderate epeirogenic elevation of the region, but this did not carry it at any time very far above sea level.

Intensive search for animal fossils at many localities in the Apache beds proved fruitless. Animals doubtless lived in the basin, which the writer believes was covered by ocean waters, but few, if any, of the forms possessed parts capable of preservation. A few fossils probably are present, but their discovery is the merest chance. From all the Beltian strata in Arizona, the single authenticated discovery of an animal fossil is that of the jellyfish reported last year (Year Book No. 35).

Study of the Ep-Algonkian surface in many of the basin ranges of southeastern Arizona and southern New Mexico shows that a peneplain with a few hundred feet of relief had been developed over a large area before the invasion of the Middle and Upper Cambrian seas. Where this peneplain is etched in Archean rock, it represents in most places further evolution of the already monotonous Ep-Archean surface. Where the peneplain transgresses the relatively weak Apache beds, it was eroded during the much shorter interval following the close of Apache deposition. The relief of the plain in southern Arizona is comparable with that of the Ep-Algonkian peneplain north of the Mazatzal barrier as shown in the splendid sections exposed in the walls of the Grand Canyon. Remnants of the Mazatzal Mountains were still conspicuous in central Arizona, and the Cambrian strata in many places abruptly abut against their bases. In southern Arizona, local eminences were present and contributed coarse débris to the invading Cambrian oceans. For example, in the Dos Cabezas Mountains southeast of Wilcox, the basal conglomerate of the Middle Cambrian Bolsa quartzite contains quartzite and a lesser number of granite boulders up to 3 feet in diameter; these apparently were derived from a residual lying to the north. In most places, however, the basal Cambrian conglomerates are of medium to fine texture.

von Koenigswald, G. H. R., Bandoeng, Java. *Anthropological and historical studies relating to the earliest evidence of man.*

These studies have been supported during the past year with financial aid from the Carnegie Corporation of New York to the Carnegie Institution of Washington.

<sup>1</sup> N. H. Darton, A résumé of Arizona geology. Univ. of Arizona, Bull. 119, 264-266 (1925).



*America*—At the invitation of the Carnegie Institution, Dr. von Koenigswald came to America to participate in the 125th Anniversary of the Academy of Natural Sciences of Philadelphia and to present on that occasion a paper, "A review on the stratigraphy of the Pleistocene of Java and its relations to early man."

In the Pleistocene of Java three different zones can be distinguished, each with typical guide fossils. First is the Djetis zone of lower Pleistocene age, where we still have *Machairodus*, *Leptobos*, *Nestoritherium*, and other Pleistocene types together with *Stegodon* and primitive elephants. Of man, there was found in this zone in 1935 an extraordinary infant skull, which shows primitive characters. This skull, which has been described under the name of *Homo modjokertensis*, may perhaps belong to an infant *Pithecanthropus*, but we still have no material for comparison, and the classical skull cap from Trinil comes from the middle Pleistocene Trinil zone. In the latter, the guide fossil is a highly specialized elephant, *Elephas* cf. *namadicus*. The so-called *Pithecanthropus* molars from Trinil can now be proved to belong to a fossil orang, found meantime in the Trinil layer in Central Java. As we have found in the same layer stone implements, small flakes of "Clactonian" type, which seem—as compared with the extremely primitive implements used by *Sinanthropus*—too well made for such a primitive human being as *Pithecanthropus*, it becomes more possible that the femur from Trinil may belong to a second and more highly specialized man, who lived in Java at the same time. This man perhaps also made the large flakes and hand axes of Chelleo-Acheulian type, discovered on an old peneplain in the Southern Mountains. In the upper Pleistocene river terraces of Ngandong, fragments of eleven human skulls have been found, belonging to the Neanderthal type, very much resembling the Rhodesian skull. The broken skulls show traces of head hunting.

A full report of this lecture will be published in the report of the meeting.

A complete collection of casts of the newly discovered human skulls and typical series of palæolithic implements, of various guide fossils, and of tectites were brought to Philadelphia and exhibited during the meeting.

After the Congress, Dr. von Koenigswald visited the American Museum of Natural History in New York, to study material from the Siwalik of India; the American National Museum in Washington; the Field Museum in Chicago; the Colorado Museum in Denver; the University of California in Berkeley.

*China*—In Tientsin the Hoang Ho Pei Ho Museum was visited, with its important collections of the Nihowan fauna. Of special interest are the collections of fossil proboscideans and horses. Two weeks were spent in Peiping. Professor Dr. F. Weidenreich kindly made it possible to study the actual *Sinanthropus* finds. Especially the large material of teeth is astonishing, and will give new points of view on the evolution of man. It is hoped that Professor Weidenreich will soon publish his results. Dr. C. C. Young kindly showed Dr. von Koenigswald the remains of fossil mammals from Chou-Kou-Tien and spent two days with him on the site, inspecting the excavations. The common opinion that Chou-Kou-Tien is a fossil cave appears untenable. What seems to be the roof is a breccia, more

cemented by lime than the rest. The site has probably always been an open fissure, perhaps a kind of canyon, at the bottom of which man camped from time to time, and which is completely filled by débris coming from the tops of the hills, covering the remains of *Sinanthropus*.

A short visit was made to the new Museum of the Geological Survey in Nanking.

In every Chinese drug store teeth of fossil mammals from China are sold as "dragon teeth." For the past few years, Dr. von Koenigswald has endeavored to collect and to study this drug store material, which is very important, containing teeth of fossil anthropoids and even of fossil man. In 1935 he went twice to China for this purpose, and he is now continuing his studies on this subject. In America, together with Dr. Stirton from Berkeley he was able to identify in Chinese drug stores in New York and in San Francisco remains of fossil Chinese mammals, imported to America. In Shanghai, Professor B. E. Read, of the Lester Institute for Medical Research, kindly assisted in these investigations.

In most cases the material is found to be from the Pontian *Hipparion* fauna, as already described by M. Schlosser from drug store material. Among the common material some rare species (as *Sinotherium*, *Anchitherium*, *Mastodon*, *Samotherium*, giant *Hyænas*) and also some new species (*Chalicotherium*, *Hyænarctos*, large rodents) have been collected. The Nihowan fauna is rare in this material; in most cases only the large teeth of *Equus sanmeniensis* and *Probosciohipparion* are observed. Only twice, in Peiping, fossils from Chou-Kou-Tien were found.

Of special interest is a Pleistocene cave fauna from the caves in Kwangsi, since this fauna shows relations between southern China and Java. A first report was published in 1935. A large quantity of selected new material has now been obtained in Hongkong and Canton. Good material of *Ursus*, *Æluropus*, and other carnivores, and about 200 teeth of fossil anthropoids, are included. Most of the teeth belong to orang, a few to *Hylobates* and *Siamang*. Two lower molars and one premolar belong to *Gigantopithecus blacki*, the largest known anthropoid. Two teeth of man are collected; they show the same preservation as the other material and are too large for recent man. They are different from the teeth of *Sinanthropus*, but of the same size, and seem to indicate a new species of fossil man in the Pleistocene of China.

*Java*—The research on fossil man in Java, begun in 1935, is being continued on a much broader base.

In the Pliocene layers in western Java (near Cheribon) no traces of fossil anthropoids have previously been found.

In the Southern Mountains (Goenoeng Kidoel) more palæolithic stone implements were collected, among them good types of Chelleo-Acheulian hand axes. The rock fissures yielded new material of fossil orang and a very interesting primitive human upper molar, perhaps belonging to *Pithecanthropus*.

The Trinil layers north of Solo have been studied carefully, and quite a number of fossils and primitive stone implements have been found. The most important finds are a mandible and a skull cap of *Pithecanthropus*.

The mandible was found in 1936 and was recognized by Dr. von Koenigswald directly after his return among the material collected for him during his absence from Java; the skull cap he collected on August 13.

The mandible is very heavy, with large teeth. A part of the right ramus is preserved, with M3 to P4, and the alveoles of P3 to I2. The alveole for the canine is small. The P4 is large as in *Sinanthropus*. The third molar is the largest and without traces of reduction. The wrinkling of the crown of the molars is more complicated than in recent man but less than in *Sinanthropus*, and is more similar to that of Neanderthal man.

The skull cap, also a surface find, was terribly broken and is at the moment not fully prepared. It shows the same characters as the famous skull cap discovered by Professor Dubois in Trinil, but is more complete, having the temporal region preserved. The position of the ear, a fossa for the articulation of the mandible, and a tuber mandibularis are typically human; but very apelike is the absence of a well-developed processus mastoideus.

By these new finds it can be definitely proved that *Pithecanthropus* is human. And, lacking a well-developed processus mastoideus and having an unreduced third lower molar, he is the most primitive fossil man now known.

## PHYSICS

**Committee on Coordination of Cosmic-Ray Investigations.** *Progress report for the period July 1936 to June 1937.* (For previous reports see Year Books Nos. 32-35.)

### INSTRUMENTAL OPERATION

The installation and operation of the Institution's precision cosmic-ray meters were continued during the year as follows: In cooperation with the Institution's Department of Terrestrial Magnetism, meter C-1 was continuously operated by the United States Coast and Geodetic Survey at its Cheltenham Magnetic Observatory; George Hartnell, of the Observatory's staff, had immediate charge of the meter, being assisted from time to time by S. E. Forbush, of the Institution. Meter C-2 continued in operation at the Huancayo Magnetic Observatory in Peru. J. W. Beagley, of the Christchurch Magnetic Observatory, was in charge of the operation of meter C-5 at Amberley, New Zealand, in cooperation with the Department of Scientific and Industrial Research of New Zealand and the Director of the Christchurch Magnetic Observatory. Meter C-4 was installed in the special housing built last year on the grounds of the National Astronomical Observatory of Mexico at Teoloyucan, D. F.; this installation was delayed because of some necessary tests of the meter and was made during February 1937 by Dr. Compton and by Professor Manuel Vallarta, of the Massachusetts Institute of Technology, with the kind cooperation of Sr. Mongez Lopez, Director of Physical Sciences at the University of Mexico, and Dr. Joaquin Gallo, Director of the National Astronomical Observatory, since which time it has been in continuous operation under the supervision of Dr. Gallo. The Committee is under obligation to Dr. Luis Quintanilla, Counsellor of the Mexican Embassy at Washington, for his kind offices in arranging for free entry of the apparatus into Mexico.

Another of the meters, under the direction of Dr. Compton, was mounted for thirteen voyages for the year ending January 1937 on the steamship *Aorangi* plying between Vancouver, Canada, and Sydney, Australia, and since January has been on board the steamship *Talune* plying between Sydney and Hobart, Tasmania. The main objectives for this installation were to obtain comparison of cosmic radiation in the Northern and Southern hemispheres and to obtain data bearing upon possible variations of the intensity of radiation with the different seasons. Still another meter was used by Professor R. D. Bennett at the Massachusetts Institute of Technology during the year for experimental work in connection with the program on high-altitude studies of cosmic radiation. The seventh meter is being held at the University of Chicago for experimental and development work in the expectation that it will be ultimately installed at Godhavn, Greenland.

The Institution's three Millikan-Neher cosmic-ray meters have been utilized during the year for the purpose of obtaining simultaneous records for the investigation of the magnitude and importance of instrumental differences. All three were for a time mounted in the radio laboratory of the Department of Terrestrial Magnetism at Kensington, Maryland, in charge



of Dr. S. A. Korff and S. E. Forbush. Later one of these meters was taken by Dr. Korff to Peru, where records of cosmic radiation were obtained simultaneously for one month at the Huancayo Magnetic Observatory, thus furnishing data for a comparison of the performance of this meter and the Institution's precision meter installed there. The records at Kensington will also afford a comparison of the two types of instruments through the records obtained there and at the Cheltenham Magnetic Observatory. It is hoped that these data, which are to be reduced and discussed by Messrs. Korff and Forbush, will make it possible to obtain a statistically adequate determination of the relative performances of various instruments of the same type and of different types; this subject is one of considerable importance in the investigation of possible short-period and long-period variations in cosmic radiation and has been repeatedly emphasized by the Committee.

Special precautions were taken to make sure that the various cosmic-ray meters were in good working order at the several stations during the total solar eclipse of June 8 in view of the potential value of the records in connection with the study of other records obtained at the same time.

As reported last year, continuous photographic recording with the Steinke cosmic-ray apparatus was continued at the University of Cape Town. This work was under the supervision of Dr. B. F. J. Schonland until December 1937. Upon his appointment as Director of the Bernard Price Institute of Geophysics at Johannesburg, the responsibility for this apparatus was taken over by Professor A. Ogg, of the University of Cape Town, and, upon his retirement, by Professor R. M. James, of the Department of Physics of the University, who was assisted by P. Gaskell immediately in charge of the meter.

Special apparatus for determination of cosmic radiation in the upper atmosphere by observations on airplanes and on pilot sounding balloons was further developed by Drs. Millikan, Johnson, and Korff. Details of these developments are given in the reports which follow; these show excellent progress and the attainment of effective records from much higher altitudes than have heretofore been possible.

#### INVESTIGATIONS

S. E. Forbush has spent part of his time on the staff of the Department of Terrestrial Magnetism during the past year in reducing and investigating the records obtained at Cheltenham and at Huancayo. He made sealings of departures from balance, of bursts, and of barometric pressure for the records from these observatories. Memoranda based on the studies by him of performance of the Huancayo and Cheltenham meters have been prepared looking toward the improvement of records at the several stations. These have proved useful, especially in eliminating loss of record and in expediting reductions. Saturation-characteristics of the ionization-chambers used at Cheltenham and at Cambridge have been determined in cooperation with Professor Bennett. Utilizing the data for Cheltenham, Huancayo, Christchurch, and Cape Town, Forbush has begun investigations of barometric effect, solar diurnal variation, sidereal diurnal variation, and lunar

diurnal variation. His results are briefly summarized in the report which follows.

The discovery of a relationship between disturbances of cosmic radiation and of the Earth's magnetism was made by Forbush using data obtained with the meters at Cheltenham, Huancayo, Teoloyucan, Christchurch, and Cape Town. This discovery, largely made possible by the installation of the Institution's meters at world-wide stations, may prove useful not only in furthering knowledge of the energy-distribution of cosmic rays, but in providing valuable evidence regarding the location of the current-system responsible for magnetic storms.

The results of Dr. Compton's investigations on difference in cosmic-ray intensity between Northern and Southern hemispheres are summarized in his appended report. Professor R. D. Bennett, of the Massachusetts Institute of Technology, and D. Heyworth, of Wellesley College, have under way an analysis of the Cheltenham data seeking a correlation between frequency of bursts and solar time.

In the laboratory and in the field, Dr. Millikan and his associates have made important advances in studies of latitude-effects up to the top of the atmosphere, on the measurement of the energies of cloud-chamber tracks, on sea-level cosmic-ray showers as a function of latitude, on the frequency of showers below sea-level, and on the development of a cosmic-ray telescope, as related in Dr. Millikan's appended report.

Dr. Johnson has devoted his time more particularly to the nature and energy-distribution of the primary cosmic radiation through unidirectional measurements at sea-level and radio-balloon measurements in the stratosphere.

Dr. Korff has also made substantial contribution in the measurement of cosmic radiation in the stratosphere, his results, as indicated in the appended report, showing high-altitude data in excellent agreement with those obtained on the stratosphere-balloon *Explorer II*. It is noteworthy that his results show, for latitudes of north and central United States, agreement with the three other techniques used by Gish, Millikan, and Swann.

#### FUTURE PROGRAM

Making use of funds provided by the Carnegie Corporation of New York for these studies and with due regard for elimination of duplication, the recommendations of the Committee for apportionment of such funds in 1937, as approved by President Merriam, were as follows: (1) continuation of program with precision cosmic-ray meters; (2) continuance of program of high-altitude research to include observations on mountains and by balloons and special radio recording devices; (3) development of cosmic-ray counter-technique; (4) intercomparisons of results obtained by different types of instruments; (5) full- and part-time services of assistants for work being done by Dr. Millikan and for analyses of data obtained from precision meters. The unexpended balances from allotments made for items indicated in previous reports have continued available for the purposes for which they were originally made.

As in previous years, the Committee wishes to record its obligation to the Union Carbide and Carbon Corporation, which has generously provided through Dr. Compton the necessary batteries for the operation of the precision cosmic-ray meters.

The work of the Committee was carried on through correspondence and conferences. Members of the Committee had the privilege of conferring from time to time with Drs. R. D. Bennett, A. H. Compton, T. H. Johnson, S. A. Korff, and R. A. Millikan, research associates of the Institution, and with others as mentioned above and in the reports which follow.

W. S. ADAMS  
J. A. FLEMING  
F. E. WRIGHT

**Compton, A. H.,** University of Chicago, Chicago, Illinois. *Studies of cosmic rays.* (For previous reports see Year Books Nos. 31-35.)

The work which we have done during the past year with funds made available by the Carnegie Corporation of New York in cooperation with the Carnegie Institution of Washington has consisted chiefly of (1) operating one of the Carnegie Institution's meters on shipboard between Vancouver and Sydney; (2) putting into operation a cosmic-ray observatory at Teoloyucan, Mexico; and (3) analyzing some of the data that have been received.

Records were obtained, with the help of First Officer R. N. Turner, during 13 voyages of the R. M. S. *Aorangi* between Vancouver, Canada, and Sydney, Australia, from January 25, 1936 to January 18, 1937. The meter was then placed on board the S. S. *Talune*, plying between Sydney and Hobart, Tasmania. From these repeated records, the facts regarding latitude-effect are being established with a higher order of precision.

The observed minimum of cosmic-ray intensity near the equator averages 10.3 per cent less than the intensity at Vancouver, in satisfactory agreement, considering the difference in experimental conditions, with earlier measurements. The critical latitudes, above which changes in intensity are less rapid, are found to be somewhat lower,  $38^{\circ}4$  N. and  $34^{\circ}2$  S., than previously reported, and beyond these latitudes the intensity is found to continue to increase with latitude. At the higher latitudes is observed a variation which appears to be seasonal, with the maximum in the cold months in both hemispheres. This variation is closely correlated with the atmospheric temperature. It is hence ascribed to changes in some atmospheric barrier of unknown nature, such as perhaps an atmospheric potential-gradient, of whose strength the temperature of the atmosphere is an approximate but not exact index.

When changes in this atmospheric barrier have been approximately allowed for by determining the external temperature-coefficient and correcting the observations accordingly, the remaining latitude-effect curves should show the effect of the earth's magnetic field alone. They are now nearly flat beyond the critical latitudes, and show a magnetic latitude-effect of about 7.2 per cent. This implies that a latitude-effect of about 3.1 per



cent owes its origin to the atmospheric barrier. Geomagnetic analysis of the energy-distribution of the rays indicates a prominent component with a sharp energy-threshold of about  $7.5 \times 10^9$  ev., and a component so weak as to be questionable, whose energy-threshold is not greater than  $2.5 \times 10^9$  ev. It is not found possible to explain the  $7.5 \times 10^9$ -ev. threshold in terms of atmospheric absorption as has previously been supposed. It may be due to a threshold of energy of particles admitted by the sun's magnetic field, as suggested by Vallarta.

The difference in cosmic-ray intensity between the northern and southern hemispheres under comparable conditions, when corrected for the effect of the atmospheric barrier, appears to be no larger than the probable error of about  $\pm 0.1$  per cent. This result is in conflict with our prediction of an excess in the north of about 0.5 per cent, due to the motion of the earth with the rotation of the galaxy, but is not inconsistent with the small diurnal variation that has been found to follow sidereal time. This would seem to imply that the cosmic rays share to a large extent the rotational motion of the galaxy.

The diurnal variations following solar time are found to be of about the same amplitude (0.3 per cent) at all latitudes. At the equator, where seasonal changes are absent, the intensity is 0.4 per cent less in January than in July. Since, owing to the ellipticity of the earth's orbit, rays from the sun should be about 7 per cent more intense in January, this is new evidence that no appreciable cosmic radiation comes from the sun and suggests rather that the sun's magnetic field may serve as a barrier to the rays.

With the kind cooperation of Sr. Mongez Lopez, Director of Physical Sciences at the University of Mexico, Dr. Joaquin Gallo, Director of the National Astronomical Observatory, Professor Manuel Vallarta, of Massachusetts Institute of Technology, and others, one of the Model C meters was put in operation in an observatory built for the purpose at Teoloyucan, about 30 miles north of Mexico City. The observatory is being operated under the supervision of Dr. Gallo, and has given almost continuous records since it was started in January.

The most significant observation as yet made from these records was the marked decrease in cosmic-ray intensity on April 25 and 26, coincident with the great magnetic storm on those dates. When Mr. Forbush reported similar findings from the records taken at Cheltenham and Huancayo on those days, a comparison showed that the change in cosmic rays was within experimental error simultaneous and of the same percentage as observed in Peru, Mexico, Cheltenham, and Chicago. In view of the differences in latitude, altitude, and shielding (the Chicago meter had only 3 cm. of lead shield), the cosmic-ray change associated with the magnetic storm is thus evidently of a very fundamental type.

Complete responsibility for operation of three of the Model C meters, at Cheltenham, Huancayo, and Christchurch, has been transferred to the Carnegie Institution's Cosmic Ray Committee; that for a fourth, to Professor Ralph Bennett at Massachusetts Institute of Technology. When the operators of the Teoloyucan meter have their program well in hand, this will likewise be taken over by the Committee. The sixth meter is being



prepared for cold-weather operation in Greenland. The seventh, which is now on shipboard, will continue to operate for the immediate future under our supervision.

We wish to thank the Cosmic Ray Committee, and especially Dr. Fleming and Mr. Forbush, for their helpful cooperation in the operation of these meters. To Dr. Wm. P. Jesse, of the University of Chicago, we owe thanks for his careful handling of many details. Professor M. S. Vallarta gave generously of his time in going to Mexico to give invaluable help in establishing the cosmic-ray observatory there. The valuable cooperation of Sr. Professor Mongez Lopez and of Dr. Joaquin Gallo in this connection has been mentioned above. Without the skillful help of First Officer R. N. Turner, of the motor ship *Aorangi*, and the cordial cooperation of Professor O. U. Vonwiller, of the University of Sydney, the Pacific Ocean data could not have been obtained. Mrs. Ardis Monk and Mr. Piara Gill have given valuable help in reducing the records to usable form. We wish to express our continued thanks to the Union Carbide and Carbon Corporation, who are supplying the specially constructed Eveready batteries for the operation of the meters. The Canadian-Australasian Steamship Company and the Union Steamship Company of New Zealand have kindly given us space on their ships for the operation of our meter.

**Forbush, S. E.**, Department of Terrestrial Magnetism, Washington, District of Columbia. *Cosmic-ray investigations.*

*Diurnal variation at Cheltenham*—Cosmic-ray data from precision cosmic-ray records obtained at the Cheltenham Magnetic Observatory from April 1935 to October 1936 were subjected to statistical analysis. The results definitely demonstrated the existence of a statistically real solar diurnal variation in recorded cosmic-ray intensity. The cause for this diurnal variation is not yet known. However, the statistics obtained in the analysis will be most useful for testing possible mechanisms, and also for investigating the more important question which concerns the existence of a sidereal diurnal variation.

The analysis also indicated two other results which are vitally important to the problem of determining whether a sidereal diurnal variation exists. These are: (1) The barometric coefficients derived from different samples of data are statistically in agreement; and (2) the observed solar diurnal variation is independent of the diurnal variation in atmospheric temperature, as measured near the ground.

*Diurnal variation at Huancayo*—Preliminary analysis of the cosmic-ray data from the Department's Huancayo Magnetic Observatory indicates a solar diurnal variation roughly in agreement with that obtained at Cheltenham. The former may be subject to some correction, depending upon the finally adopted barometric coefficient.

*Effect of magnetic storm on cosmic-ray intensity*—Cosmic-ray data from Cheltenham (United States), Huancayo (Peru), and Teoloyucan (Mexico), during the magnetic storm which began April 24, 1937, all indicated similar changes which were simultaneous with the changes in the horizontal com-

ponent of the Earth's magnetic field. The latter decreased about 0.5 per cent during the storm, while the cosmic-ray intensity decreased nearly 4 per cent at all three stations. The hypothesis was advanced that the decrease in cosmic-ray intensity was due to the external magnetic field of the current-system in the upper atmosphere which is presumably responsible for the magnetic effects of the storm. In the space external to the current-system, the Earth's field is augmented (during the main phase of the storm) in approximately the same way as if the magnetic moment of the Earth had increased. The analyses of Lemaître, Vallarta, and Störmer have shown that the cosmic-ray intensity at any given point on the Earth, or above it, should decrease if the Earth's moment increases. Thus, during the main phase of a magnetic storm, one should expect a decrease in cosmic-ray intensity in the region outside the current-system and also at the Earth's surface, provided one neglects the effect on cosmic rays of the field of the current-system in the space between it and the Earth. The magnetic-storm effect on cosmic-ray intensity may provide important evidence for determining the height of the current-system of magnetic storms.

*Sidereal diurnal variation*—Preliminary investigation of the sidereal diurnal variation from the Cheltenham data has been effected. The results do not indicate a sidereal effect which can be regarded as statistically real. The sidereal effects which others have found and regarded as real have been examined and it is concluded that these cannot be regarded as real until statistical tests have been applied. Furthermore, it was found that the corrections for temperature of the external air which were applied to Hess's data would result in an apparent sidereal diurnal variation.

*Lunar diurnal variation*—Preliminary investigation of the lunar diurnal variation in cosmic-ray intensity based on the Cheltenham data did not indicate the existence of a statistically real lunar effect. It is planned to continue this investigation in conjunction with the analysis of the solar diurnal variation for the Huancayo data. The results will be of interest chiefly to determine whether the Moon's magnetic moment is sufficient to affect the paths of cosmic rays.

*Solar diurnal variation of bursts*—Preliminary analysis of bursts for Huancayo (by months) indicates a diurnal variation which is possibly due entirely to diurnal variation in barometric pressure.

The contributions made in these investigations necessarily depend upon the excellent maintenance of the meters by the several cooperating organizations and observers. The writer is particularly under obligation to Messrs. George Hartnell, J. W. Beagley, and O. W. Torreson and F. T. Davies, of the Cheltenham, Christchurch, and Huancayo observatories, respectively.

**Johnson, Thomas H.**, Bartol Research Foundation, Swarthmore, Pennsylvania. *Studies of cosmic rays*. (For previous reports see Year Books Nos. 32-35.)

Working under grants from the Carnegie Institution, investigations bearing upon the nature and energy-distribution of the primary cosmic radiation have been continued, as follows.

1. *Unidirectional measurements of cosmic-ray intensities at sea-level* with reference to their dependence upon latitude and direction have been continued. The apparatus used last year was overhauled and sent on five voyages across the equator from New York to San Antonio, Chile, on the Grace Liner *Santa Lucia* during the period June 1 to December 31, 1936. This instrument records cosmic rays from the vertical and from the inclined directions  $45^\circ$  from the zenith in eastern and western azimuths. As indicated by the results of the previous year, it was again found on all five voyages that the vertical intensity passes through a minimum at a point about  $15^\circ$  north of the geomagnetic equator and there is a definite lack of symmetry in the intensity *vs.* latitude curve on the two sides of the minimum. These characteristics are out of accord with the eccentric dipole theory of the cosmic-ray-intensity distribution which predicts a symmetrical curve in this longitude with minimum at the geomagnetic equator. The magnitude of the vertical latitude-effect between the point of minimum intensity and  $40^\circ$  N. geomagnetic latitude was found on all voyages to be about 12 per cent of the high-latitude value. Because of the shorter average path of rays through the atmosphere in the vertical direction, this result is considered in agreement with the 8 per cent latitude-effects measured over the same range with ionization-chamber technique. Between  $40^\circ$  and  $50^\circ$  N. geomagnetic latitude the results of different voyages were at variance with one another, some showing an increase of intensity up to an additional 6 per cent while others showed no further increase north of the  $40^\circ$  parallel. Although tests are being made of the possibility of accounting for such variations in terms of temperature- or humidity-effects in the instrument, it is also noted that similar variations appear in the results of other investigators who have used ionization-chamber technique for measuring latitude-effects, and they are of the order of the seasonal variations recorded at the permanent stations on land.

In the western direction the average of all voyages shows a latitude-effect of 4 per cent, whereas in the eastern direction there is an average latitude-effect of 12 per cent. The 8 per cent difference is in agreement with the asymmetry measured directly at the equator. The smallness of the western latitude-effect constitutes direct evidence, independent of the precise theory of the allowed cone, of the great preponderance of the positive primaries in the radiation producing sea-level effects. Calculations based upon the new results of unidirectional recordings and the Lemaître-Vallarta theory of the allowed cone show an upper limit of about 30 per cent of the sea-level intensity which can be attributed to negative primaries, but the uncertainty in the result, due for the most part to the failure of the theory to account for the anomalous distribution cited above, does not allow the possibility to be excluded that there are no negative primaries in evidence at sea-level.

2. *Radio-balloon measurements of cosmic-ray effects in the stratosphere.* The importance of stratospheric measurements of cosmic radiation over a wide range of latitudes with attention to directional effects has become increasingly apparent. Asymmetry measurements at the equator are required to determine the distribution between the two signs of charge of the pri-



mary rays at the top of the atmosphere; vertical intensity as a function of atmospheric depth at different latitudes must be measured to complete our understanding of the absorption of high-energy particles; and the energy-distribution of primary rays in the lower ranges of energy, where the sun's magnetic field can possibly be the determining factor, must be investigated by a latitude-survey using the same technique. Flights in the spring of 1936 laid the foundation for our first successful cosmic-ray measuring flights, launched and recorded on the summit of Mount Washington, New Hampshire, in September 1936. Coincidences per minute as a function of barometric height were determined from the radio signals sent out from the balloon and curves were plotted having the features characteristic of the results of other investigators who had used the older technique of photographic recording in the balloon. These flights proved the advantage of an isolated receiving station with a clear horizon and they led to several improvements in design of apparatus. With the improvements, three flights were then made, two of which were successful, from the Hopewell fire-tower of the Pennsylvania Department of Forests and Waters during May and June. One of these flights reached an altitude of 43.5 mm. of mercury and gave an excellent record of cosmic-ray intensity. The flight lasted 160 minutes and the signals were received throughout until the balloons had returned to within a mile of sea-level.

Fifteen more instruments have now been assembled, with which it is hoped to measure latitude-effects at the top of the atmosphere and the intensity *vs.* elevation at three stations evenly distributed between  $46^{\circ}$  N. and  $59^{\circ}$  N. geographic latitude. These measurements will be undertaken during the summer of 1937. Developments for controlling the azimuthal orientation of the balloons for asymmetry measurements are also being made.

*Cooperation.* Dr. Donald N. Read has assisted in the measurement of the sea-level latitude effects.

The Grace Lines have allowed us, without charge, to place the instrument on the *Santa Lucia*.

Mr. A. A. MacKenzie has been of important assistance in the development of the radio balloon-technique, and his experience with the radio meteorograph technique of the Blue Hill Meteorological Observatory has been a valuable asset.

Mr. John Marshall Jr. has assisted with the flights and with the assembly of instruments.

The Pennsylvania Department of Forests and Waters, through the courtesy of E. F. Brouse, District Forester, has placed at our disposal the excellently adapted facilities of the Hopewell fire-lookout tower.

**Korff, S. A.,** Department of Terrestrial Magnetism, Washington, District of Columbia. *Studies of cosmic rays.*

In accordance with a decision of the Committee on the Coordination of Cosmic-Ray Researches of the Institution, work was started on a program of comparing the various cosmic-ray observing techniques, and studying the differences between them. As is well known, there has been some



disagreement among several of the competent cosmic-ray observers, not only regarding interpretations but also regarding actual measurements. It is further noted that each observer has heretofore developed his own observing technique, and that hitherto these techniques have not been intercompared. Several angles of attack on this problem have been started and are being simultaneously carried out.

*Program with Millikan-Neher meters*—The three Millikan-Neher type cosmic-ray meters of the Committee were installed in the radio laboratory of the Department of Terrestrial Magnetism at Kensington during February 1937. Two were put inside lead shields, and the third was operated without lead. The purpose of this investigation is to determine whether two identical instruments will, over a period of time, record the same changes in intensity. Therefore the meters are being operated continuously, and after six months of simultaneous records are available they will be reduced and investigated.

*Comparison of cosmic-ray meters*—A Millikan-Neher type meter was installed next to one of the Committee's precision cosmic-ray meters of the design by Compton and Bennett in the Huancayo Magnetic Observatory in Peru and operated continuously for six weeks. The records are now being measured and intercompared, to see if the two respond similarly to fluctuations.

*Counter-work*—In order to compare observations by counter and by electroscope, especially in the critical regions at high altitudes, a type of radio-sonde counter-apparatus was developed, designed, and built. A series of flights was made in Washington in cooperation with the National Bureau of Standards and the United States Weather Bureau; during these a marked secondary peak in the radiation was discovered. The existence of the peak had been suspected from observations by counters in the flight of the *Explorer II* but it was brought out very markedly by the new technique. It is notable that a definite difference between results by counters and by electroscopes comes out at this point, since electroscope-observations smooth out the peak almost entirely, while counters bring it out sharply.

The counter-apparatus was then removed to Lima, Peru, and there a series of five flights was made. Good curves were there obtained, which show a very much lower intensity of cosmic rays at high altitudes in this region. The electroscope, en route to Huancayo, was carried to an altitude of 18,000 feet in an airplane. The observations bring out the following results:

1. The intensity of ionization produced by cosmic radiation at high altitudes in Peru is about half that at Washington; thus the latitude-effect at high altitudes is found to be 50 per cent.
2. The maximum intensity in Peru is reached at about 45,000 feet, as compared with the maximum at about 55,000 feet over Washington. This shift is due to the softer component's being cut off by the Earth's field and not reaching the upper atmosphere in Peru.
3. At higher altitudes, up to 70,000 feet, the intensity is found to fall off by about 30 per cent, indicating that a large part of the ionization at high elevations is due to secondaries.

4. The comparisons of counters and electroscopes yield similar increases of ionization with altitude, showing that these two different techniques give good measures of the total intensity of cosmic rays.

*Eclipse-observations*—At the invitation of the American Museum of Natural History, Dr. Korff joined the expedition of the Museum to photograph the solar eclipse of June 8, 1937. A polar axis was set up at Moro, Peru; on it was mounted a camera with lens 6 inches in diameter and of 90-inch focus. An exposure schedule of 1, 2, 4, 8, 16, 32, 64 seconds was arranged. The photographs show good definition. Photometric reductions will probably be performed on these plates by Professor Miller, of Swarthmore Observatory.

The Huancayo cosmic-ray record will be carefully examined for any possible effect due to the solar eclipse. The Millikan-Neher meter was operated also on the boat en route to Peru for further check on the latitude-effect in cosmic rays.

It is a pleasure to acknowledge the cooperation of various individuals and institutions. Among these are especially Dr. J. C. Merriam, Dr. J. A. Fleming, the Institution's Committee on Coordination of Cosmic-Ray Investigations; the Peruvian Government, whose officials helped in many ways; Dr. L. J. Briggs and Dr. L. F. Curtiss, of the National Bureau of Standards—the latter the designer of the barographs used in the flights. Considerable advisory assistance with regard to balloon-technique was received from the United States Weather Bureau.

**Millikan, Robert A.**, California Institute of Technology, Pasadena, California. *Studies of cosmic rays*. (For previous reports see Year Books Nos. 31–35.)

The cosmic-ray investigations carried on at the California Institute of Technology during the academic year 1936–1937 with the aid of funds provided by the Carnegie Corporation of New York administered by the Carnegie Institution of Washington have yielded results of very fundamental and far-reaching importance, which may be very briefly summarized as follows:

#### I. STUDIES BY BOWEN, MILLIKAN, AND NEHER ON LATITUDE-EFFECTS UP TO THE TOP OF THE ATMOSPHERE

1. The curve obtained by taking the differences between our ionization-depth curves obtained at San Antonio (Texas) and at Madras (India) gives full knowledge of the ionization produced in the atmosphere *by a band of entering electrons of energies between  $6.7 \times 10^9$  and  $17 \times 10^9$  electron-volts*. These Madras–San Antonio experiments have therefore made it possible for the first time to determine experimentally the general law of nuclear absorption of electrons by the atoms of the atmosphere up to energies of 17 billion electron-volts. The results show, contrary to the most approved of preceding assumptions, that electrons even of that huge energy, instead of being highly penetrating, are so rapidly absorbed by nuclear collisions in the upper layers of the atmosphere that they reach their maximum of ionization by the time they have got but one-twentieth of the way through

it, and at half the way through they have retained not more than one-sixteenth their ionizing power. This very high absorbability of electrons, even of very high energies, is in accord with the requirements of the Bethe-Heitler theory. The experiments therefore remove what have been heretofore regarded as the insuperable objections to the validity of that theory for electrons of very high energies. They force the conclusion that the high-energy penetrating particles, definitely revealed in great numbers both by cloud-chamber photographs and by ion-counter experiments at sea-level, are not ordinary electrons at all, though they carry the electronic charge and produce tracks thus far undifferentiable from electron-tracks (+ and -). Otherwise stated, our experiments show that electrons clear up to an energy of 17 billion electron-volts make "radiative collisions" and are therefore rapidly absorbed by air, so that the *observed, penetrating* particles are not electrons. They must be either protons or else particles of intermediate mass between protons and electrons. If they are protons, since they are both positive and negative in sign, the negative proton has been discovered. *In any case a new particle has come to light*, as Anderson and Neddermeyer have already announced for other reasons (see below).

2. By taking curves similar to the San Antonio and Madras curves in magnetic latitude  $51^{\circ}3$  N. (Omaha) and magnetic latitude  $60^{\circ}$  N. (Saskatoon), we reach the conclusion that *practically the whole energy-content of the latitude-sensitive incoming rays is found in a band between  $3 \times 10^9$  and  $17 \times 10^9$  electron-volts.*

3. We find by integrating our curves that the total energy brought into the earth's atmosphere by the latitude-sensitive rays is about the same as the total energy brought to the earth by the non-field-sensitive rays.

4. From the similarity in shape between the curves corresponding to the field-sensitive and the non-field-sensitive incoming rays, as well as from a comparison of energies represented by these curves, we reach the conclusion that they do not permit an appreciable number of *incoming penetrating* particles to be mixed with the incoming highly absorbable rays (electrons, photons, or both). In other words, we conclude that practically all the incoming cosmic rays are of the highly absorbable type, and therefore that *the penetrating particles observed in cloud-chambers and in counter-experiments are in general secondaries (+ and -) produced in our atmosphere by the incoming electrons and photons, one or both.*

5. In order to account for the fact that at the top of the atmosphere the latitude-sensitive rays seem to be absorbed more rapidly than the Bethe-Heitler law permits, while as sea-level is approached the average penetrating power is considerably greater than that theory as extended by Carlson and Oppenheimer allows, we introduce the assumption that although the normal procedure in the process of absorption is for a photon to create an electron pair, at much rarer intervals another possible mode of absorption of a photon by a nucleus may take place. *It consists in the transfer of the energy of the photon to a penetrating particle—proton or an "X-particle"—which then acts merely as a penetrating link to carry cosmic-ray energy farther down.* This penetrating particle may then, through another nuclear collision, transform its energy back into the usual photon-electron shower.



## II. STUDIES BY ANDERSON AND NEDDERMEYER ON THE MEASUREMENT OF THE ENERGIES OF CLOUD-CHAMBER TRACKS

1. By measuring the loss of energy of cosmic-ray tracks in passing through a bar of platinum 1 cm. thick, Anderson and Neddermeyer have shown that apparent electron-tracks that are associated with other tracks—components of showers—uniformly show energy-losses such as are in accord with the Bethe-Heitler law of electronic absorption, while apparent electron-tracks not components of showers in general do not follow the Bethe-Heitler law, but instead show an extraordinarily high penetrability, *direct experiment showing that two tracks that have the same curvature may show entirely different penetrabilities*. These studies are upon a total of 55 tracks of energies from 50 million to 500 million electron-volts, so that the breaking into two groups, one absorbable and one penetrating, seems to be quite definitely established. Some of the penetrating particles are of so low an energy that the indication is that they are not protons, since protons of these curvatures should ionize more strongly than these seem to do. In any case, the experiments under I and II are in agreement in requiring a penetrability which electrons cannot theoretically possess, and, according to the experimental evidence in both I and II, do not possess.

2. Careful experiments are now under way on the counting by a refined technique of the number of ions produced per cm. of path by both the penetrating and the nonpenetrating particles, since such experiments should bring to light differences in ionizing power depending upon differences in mass.

3. In addition to the above, about 7000 photographs were taken in which the cloud-chamber was actuated by a single counter mounted inside the chamber, in an attempt to reveal heavily ionizing particles near the end of their range, where an estimate of their mass becomes possible. Several heavily ionizing particles were found, all but one of which could be ascribed to protons. The one particle seemed to possess a mass less than that of a proton.

4. In August 1936, 2000 track photographs were taken in a strong magnetic field of 16,000 gauss at Coco Solo in the Panama Canal Zone. These data provide an energy-distribution of the cosmic-ray particles in the equatorial latitudes for comparison with the energy-distribution previously obtained in Pasadena.

## III. STUDIES BY NEHER AND PICKERING ON SEA-LEVEL COSMIC-RAY SHOWERS AS A FUNCTION OF LATITUDE

1. The development by Neher of a counter which works ten times as rapidly as the usual counter has made it possible to obtain a new definiteness and precision in the study of the latitude-effect with showers. Neher and Pickering have measured the equatorial dip for showers in two different longitudes, one near Singapore, the other between Sydney and Vancouver, and have compared it with the equatorial dip obtained with a group of counters set in a vertical line. For the latter they obtained nearly the same value in both longitudes that Millikan and Neher obtained with Neher electroscopes, but with showers they obtained in both cases about half this equatorial dip.



This means that the *non-field-sensitive rays are more effective as shower-producers than are the latitude-sensitive rays of a little lower energy*—a surprising result unless the two sorts of rays are of quite different character. With suitable assumptions, however, one may avoid this conclusion.

#### IV. STUDIES BY PICKERING ON THE FREQUENCY OF SHOWERS BELOW SEA-LEVEL AND ON THE DEVELOPMENT OF A COSMIC-RAY TELESCOPE

1. Pickering finds that below sea-level the frequency of showers diminishes at about the same rate as do the cosmic-ray electroscope's currents. This is significant, since in rising above sea-level the frequency of showers increases much more rapidly than do the currents in a cosmic-ray electroscope. The result is, however, in line with those obtained by other observers.

2. A new, sensitive cosmic-ray telescope has been developed with the aid of Neher counters and is being used in the endeavor to obtain evidence for absorption-effects when pointed toward the portions of the sky in which large quantities of obscuring matter are found.

#### Committee on Study of the Surface Features of the Moon. *Progress report for the period July 1936 to June 1937.* (For previous reports see Year Books Nos. 26–35.)

During the past year the Committee on Study of the Surface Features of the Moon has continued investigation, by visual methods, of the nature of the surface materials of the moon. This problem requires for its solution detailed comparison of the effects produced on the sun's rays by reflection at the moon's surface with those produced by terrestrial materials under similar conditions. In recent years methods have been developed which are of adequate sensitiveness and reliability to be of service in a study of this kind.

The changes produced in sunlight on reflection, refraction, and scattering at the surface of the moon are of three kinds: (a) a large proportion of the energy of the incident sunlight penetrates a short distance into the surface and is absorbed, thereby heating the surface materials; the heated surface in turn radiates the absorbed energy into space as heat waves (planetary heat); (b) different wave lengths or colors of the incident sunlight may be absorbed in different proportions and thus give rise to colored scattered light (selective absorption); (c) a certain amount of plane polarization is introduced on scattering and reflection; the amount depends on the character of the material and on its surface. In general, dark-colored opaque substances polarize the light much more than do non-opaque substances into which the incident light may enter and be returned in part by internal reflections.

The proportion of plane polarization in a beam of moonlight can be ascertained by several different methods based on different types of receivers, such as the human eye (visual), the photoelectric cell, the thermoelement, or the photographic plate in a polarization spectrograph. These methods cover different spectral ranges, but their ranges overlap sufficiently so that the results obtained by one method can be checked by those obtained by other methods.

Visual determinations of the percentage amounts of the plane polarization in light from different parts of the moon at different phases have been made

by the Moon Committee during eleven lunations. As a result, the changes in amount of polarization with change in lunar phase angle are now known with a fair degree of accuracy for the light from twenty-four selected areas on the moon's surface and also for the integrated light from the entire visible lunar surface. Study has been made of the factors that influence the accuracy of the results, especially the depolarizing effects of dust particles and of water vapor (thin clouds) in the earth's atmosphere.

Similar visual measurements have been made of the amounts of plane polarization in the sun's rays after reflection by terrestrial materials of different kinds. The amount of plane polarization thus introduced depends not only on the phase angle or angle between the incident beam and the line of sight to the observer, but on the refractive and absorption indices of the material and on the nature of the surface that scatters the light, whether it is a surface of fracture, a rough or finely ground surface, or a coarse or fine powder surface. The factors that enter into the problem are many; their influence can be determined only by adequate numbers of measurements on each material under test.

The phenomena observed are chiefly those of scattered (diffracted) light combined with absorption and internal and external effects of reflection; they cannot be explained on the basis of reflection and refraction alone. When the angle between the incident and the radiated beam is small, from  $10^\circ$  to  $30^\circ$  depending on the substance and its surface, the amount of polarized light in the scattered beam is zero. For still smaller phase angles the scattered beam is again partially polarized, but the plane of vibration of the polarized component is in the plane of incidence rather than normal thereto. Lyot, who was the first to observe this phenomenon in moonlight, called it negative polarization. It appears in moonlight about two days before full moon and continues for an equal period after full moon. Terrestrial materials exhibit the same phenomenon and approximately the same range of variation. The percentage amount of negative polarization rarely exceeds one per cent and may be less. In terrestrial materials it varies with the substance and with the character of the scattering surface. It may be practically absent or occur only at small phase angles, less than  $10^\circ$ . As a diagnostic feature negative polarization is of little value. It is, however, an important element in the theory of scattering of light and should be investigated in detail. Some work has been done on negative polarization in light diffracted from gratings ruled on glass, and is being continued.

The visual measurements have been made with a special eyepiece consisting of a tilting-plate compensator together with a detector for ascertaining the point of exact compensation. With this eyepiece the percentage amount of polarization can be determined with an accuracy of one-fifth of one per cent. The percentage amount of polarization introduced by a single thin plate of glass or celluloid of refractive index 1.505 and inclined at an angle of  $70^\circ$  to the incident beam is approximately 26 per cent; at  $60^\circ$  tilt angle it is about 18 per cent; with a compensator consisting of two plates mounted in parallel and tilted at  $60^\circ$ , the percentage amount is increased to 30 per cent; with 4 plates, to 46 per cent; with 6 plates, to 56 per cent; and with 12 plates, to 71 per cent.

For observations on the moon the single-plate compensator suffices; the maximal polarization in moonlight from the dark areas or "seas" is approximately 17 per cent; from the bright lunar mountainous areas it rarely exceeds 8 per cent. For observations on terrestrial materials more than one tilting plate is needed to compensate the much higher amounts, exceeding 50 per cent, of plane polarization produced by dark-colored rocks, such as basalts and peridotites. For these materials a 6-plate compensator is required.

With the aid of the polarization eyepiece, equipped with tilting compensators of 1, 2, and 6 plates, polarization measurements have been made on fifty selected terrestrial substances illuminated by sunlight incident at different angles and viewed from different directions.

The results of visual measurements of polarization in light scattered by the moon's surface and by terrestrial materials have been plotted on graphs and are now being assembled, preparatory to a report on this part of the determinative work. Progress is being made on polarization measurements by three different photoelectric methods, and by the polarization-spectrograph method.

Study of the shapes and slope angles of lunar surface features by the grazing-incidence method proposed by the Moon Committee two years ago has been continued. The usefulness of this method will be greatly enhanced by the series of lunar photographs which are to be taken with the aid of the 100-inch telescope during an entire lunation. The new zero corrector lens for the Newtonian focus of this telescope is nearly finished and should be available for this purpose during the summer of 1938.

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## POINT LOBOS STUDIES

**Point Lobos Advisory Committee**, Point Lobos, California. *Values of primitive nature.* (For previous report see Year Book No. 35.)

Recognizing that an area like Point Lobos Reserve is a dynamic, growing thing, and that there is constant change in the many interrelated factors that make for its supreme qualities, the Point Lobos Advisory Committee has continued its studies during the past year, and in the light of further knowledge gained has made recommendations to the California State Park Commission amplifying the Master Plan and Statement of Administrative Policies adopted by them last year.

The type of investigation established at Point Lobos, as the basis of policy in land management, has come to be recognized as setting the pattern for study of values in California's State Park System, notably in the Redwood Parks. Plans are being made by the Commission for study, analysis, and classification as to the highest use of each of the seventy areas under its jurisdiction.

Notable additions to the store of knowledge about Point Lobos have been made. A report has been completed by Frederick Law Olmsted and George B. Vaughan which attempts an analysis of the esthetic features of the Reserve, dealing with these both from the purely perceptual point of view, as to such matters as form, color, and landscape composition; and from the intellectual viewpoint, as to the significant relationship of the flora and fauna to their environment and to each other, as well as their relation to the geologic past and future of the area. Important features noted in this analysis have been plotted by permanent traverse on the completed base map of Point Lobos Reserve.

Studies of the marine algae and of the lichens have been added to the plant inventory and map of vegetative cover already made, and reports rendered on the land snails and marine bird life. The extensive report on *Vertebrate animals of Point Lobos Reserve*, by Dr. Joseph Grinnell and Dr. Jean Linsdale, has been published by the Carnegie Institution of Washington as first of a series dealing with the resources of Point Lobos.

Studies of trends which may affect perpetuation or destruction of the highest values in the area have been continued. Further observation has been made of plant diseases affecting the Monterey cypress and Monterey pine. A recheck for cypress canker in the "protective zone" established around Point Lobos has revealed several instances of recurrence of the disease in planted cypresses fairly close to the Point, and the infected trees have been removed. A careful examination has been made in the Reserve, but no cases have been found.

A count and measurement has been conducted of all cypresses on the main headland, living and dead. The percentage of younger trees revealed, together with investigation of reproduction through seedlings, leads tentatively to a conclusion favorable to the perpetuation of the cypress, if it can be protected from cypress canker.



Ecological studies have included the establishment of ten permanently staked typical plots in various parts of the Reserve in which a survey of vegetation will be made periodically, to determine successional trends and other pertinent facts bearing upon future policy for protection. Weather-recording instruments have been installed and regular observations begun.

Linked with the scientific studies is the attempt to plan the regulation of human traffic, through continued study of the use of the area by visitors, in locating and designing trails, parking spaces, and the minimum of automobile roads, in such manner as to afford maximum access to the inspirational and educational features consistent with proper protection. Counts made at specified locations and on definite dates comparable with observations made last year provide the beginning of a body of data which as it accumulates can be analyzed by park administrators with increasing conclusiveness. Already marked improvement in the area has been noted as to the beauty and impressiveness of certain features, notably wild-flower growth in the meadows which have been protected from traffic, the marine invertebrates and algæ in the tidal pools along the shore, and the finer vistas obtained from relocated foot trails.

In addition to nature guide service and the preparation of publications interpreting the Reserve to the public, further means for making continuously effective the policies based upon the Point Lobos studies will be provided through the establishment, for the benefit of park officials, students, and visiting scientists, of a central headquarters building with weatherproof and fireproof vault in which will be deposited all plans, records, maps, photographs, specimens, and other data which can be readily referred to at the site. Thus it is expected that those who are intrusted with the protection of Point Lobos Reserve, with its sole remaining natural grove of Monterey cypress, its outstanding coastal landscape, and its rich flora and fauna of land and sea, can through study and vigilance attain their declared objective in its administration: "To keep at a high level of perfection the unique natural conditions upon which its highest values depend, in order to make these permanently available for the enjoyment, education, and inspiration of the public."

POINT LOBOS ADVISORY COMMITTEE: Ray Lyman Wilbur, *Chairman*; John C. Merriam, *ex officio*; Newton B. Drury, *Secretary*.

LANDSCAPE SUBCOMMITTEE: Duncan McDuffie, *Chairman*; Paul Dougherty, Allen Griffin, Mrs. Robert Hunter, Carmel Martin.

SCIENTIFIC SUBCOMMITTEE: H. A. Spoehr, *Chairman*; Douglas H. Campbell, Ralph W. Chaney, Willis L. Jepson.

## PSYCHOLOGY

**Ruger, Henry A.**, Teachers College, Columbia University, New York, New York. *Studies of correlational surfaces*. (For previous reports see Year Books Nos. 27-35.)

These studies have been continued with funds made available by the Carnegie Corporation of New York to the Carnegie Institution of Washington.

The computation of higher product moments for pairs of traits previously corrected for nonlinear regression on age has been continued throughout the year. Product moments whose exponents total from 3 to 8 inclusive were chosen. There are 27 of these higher product moments for a given pair of traits. These moments for the general population of 7000 males, age groups from 6 to 80 years, had been previously computed, except for some checking. This was done for the entire set of 28 pairs of traits. The present study involves the computation of similar product moments on the 15 consecutive age groups from 16 to 30 years, for a given pair of traits. Four pairs of traits were selected for complete treatment, i.e. for the computation of the 27 product moments for each of the four pairs of traits. These four pairs of traits were selected on the basis of the trends on age of the "product moment," total exponent 2, numerator of the Pearson "r," as exhibited in *Eugenics*, vol. 5, 364-412, for the same age groups.

During the past year the 27 product moments around guessed means have been computed for each of the chosen four pairs of traits for the 15 consecutive age groups. In addition considerable work has been done on 12 of the higher product moments for the remaining 24 pairs of traits. When these moments have been shifted to the true means, the relation of the moments in the 15 age groups to those in the entire population of 7000 will be studied. The moments of the separate traits and their ratios, the betas, are also being computed. It is hoped that this material, which, so far, has been published in full, will be helpful to investigators in the field of correlation theory. An attempt will be made to interpret the results of this entire series of studies.

An average force of five statistical workers under the supervision of Antonia von Brand has been furnished by the Works Progress Administration.

## ST. AUGUSTINE HISTORICAL PROGRAM

Chatelain, Verne E., St. Augustine, Florida. *The St. Augustine Historical Program.*

St. Augustine, Florida, among communities in the United States, enjoys the unique distinction of having had the longest continuous occupation by men of European origin. Here a colony was established by the Spanish sea captain, Pedro Menendez de Aviles, in 1565, and since then the life history of this settlement has been uninterrupted. In two different periods St. Augustine was under the rule of Spain, in another period under Great Britain, and since 1821 it has been under the flag of the United States, except for a brief time during the American Civil War.

St. Augustine, moreover, was the only Spanish colony in American history to be successfully established and maintained on the Atlantic seaboard of what is now the United States. For that reason a study of its characteristics, its growth and its progress, in comparison with other colonies planted upon our eastern shores, English, French, Dutch, and Swedish, is significant. One is reminded also that St. Augustine was for centuries the Spanish capital of Florida, a geographical term once involving generally that part of the American continent from the Gulf of Mexico north to the St. Lawrence and west to the Mississippi and its tributaries. Thus the little Spanish town, sanctioned by all the power of Spain, had a transcendent influence out of all proportion to its size and economic prosperity. From its fountainhead poured Catholic missionaries during the late sixteenth and seventeenth centuries, spreading Spanish influence along the Atlantic coast perhaps as far as the Rappahannock River in Virginia; traders into the uplands of West Florida, Georgia, and Alabama, and the Mississippi delta; and political leaders, stirring up international rivalries against the French, the British, and finally the Americans, along the Georgia and Carolina coasts, as well as along the shores of the Gulf of Mexico.

Spain's colorful history in the western hemisphere has already been the subject of intensive study by the Carnegie Institution, as it relates to the Southwest, Mexico, and Central America, and it is therefore logical that that interest should include St. Augustine, particularly since the source materials, which the preliminary studies have shown to be voluminous in quantity and widely scattered in various American and European centers, have received only a minimum amount of attention from scholars.

A further reason for the St. Augustine Program is to be found in the growing interest and concern in developing the most effective methods of preserving and using outstanding American historic sites, buildings, and remains. The Institution in its work in Central America and elsewhere has displayed a lively interest in this problem, and has contributed to the development of tentative principles in the treatment of the physical problems of history, which it now seems appropriate to transfer to a new field of investigation and to experiment with still further, in an effort to refine and eventually to perfect them. For such experimentation the St. Augustine situation appears to be well adapted. Not only are there an unusual

number of outstanding sites, buildings, and remains to be found in this ancient capital of Florida, but the city at the present time is anxious to embark upon a program for their effective perpetuation, and use by the large visiting public which annually flocks to this famous resort region.

An unusual combination of circumstances therefore has pointed to the desirability of undertaking the St. Augustine Historical Program, which was launched in the fall of 1936, when, following official action by the Mayor and the City Commission of St. Augustine, a National Advisory Committee was formed, with Dr. John C. Merriam as Temporary Chairman, and the Preliminary Survey was commenced under the auspices of the Institution. Two meetings of the National Committee have been held, one in October 1936, signaling the determination to begin the work, and the second on March 2, 1937, at the end of the Preliminary Survey, when the two sub-committees of the National Committee submitted their reports; these called attention to the great scope and importance of the historical resources, and outlined a plan of historical development and research at St. Augustine.

During the year both the city and the state of Florida also have been active in formulating plans to assist in the work. An appropriation of \$50,000 was made by the state legislature and approved by the Governor. Another state act declared that historic sites in St. Augustine are of unusual public interest and for that reason are subject to the right of eminent domain by the city to insure their perpetual protection. Finally, the legislature by the Charter Amendment Act gave the community the authority to control and refine its general physical environment through zoning measures in the interest of a more harmonious setting for its outstanding historic sites. To date considerable progress has been made in studying the nature of this proposed zoning program.

As an agency of local import, the St. Augustine Preservation and Restoration Association was organized to deal with the purely civic problems of planning, financing, and administering the historic sites program in the city. This is an incorporated quasi-public body, and is in reality an arm of the municipal government developed to carry out the purely local aspects of the St. Augustine Program. Already this Association has raised sufficient funds, in addition to those appropriated by the state, to carry the administrative and some of the research work through the first year. Recently it received a bequest in the form of a valuable collection of papers, and paintings dealing with the community in the nineteenth century.

In the progressive steps of setting up the Program the Carnegie Institution has cooperated in an advisory capacity. Having assisted in the organization of the National Committee and in the conduct of the Preliminary Survey, the Institution, since the formulation of the St. Augustine Plan on March 2, has participated actively in the general historical research program.

Conceivably the research studies of the Institution might go forward, whether or not accompanied by action on the part of the city looking toward the preservation and educational use of outstanding historic sites. Such research, because of the great importance of St. Augustine, would ap-



pear to be fully justified. Special significance, however, attaches to this research activity because of the possibility of its direct utilization in formulating and carrying out policies for protecting and interpreting physical resources which are of a major national importance.

For this reason, attention has naturally been directed at the outset of the program to those objectives calculated to suggest the methods most suitable in evaluating and preserving, as well as using, the physical resources of St. Augustine; this procedure has involved the enumeration of all historic sites, buildings, and remains, and a determination of their characteristics and placement or classification in the various stages of the community's history; the results of such procedure may be found in one phase of the research program—a series of "case histories," each pertaining to a particular site, building, or other remains.

In accomplishing this result, an effort has been made to collect as far as possible a complete series of maps and pictures of all periods relating to St. Augustine. Likewise archæological studies, carried on without interruption throughout the year, have been used to ascertain the exact location of sites and remains, and to determine all manner of facts regarding construction, materials, and other characteristics. Around these research activities the historian has collected as many other written data as possible, and has organized this material, from whatever sources developed, on each particular unit, into the "case history." Thus such "histories" are represented in the files by historical maps showing the condition of the site at different periods or dates, pictures illustrating as many stages or periods as possible, historical notes regarding the origin, development by stages of growth or change, or special events in connection therewith, architectural studies describing the physical structure as to class, period, and details of construction, and finally engineering notes and recent photographs showing the present or nearly present condition. Of course these "case histories" can and should be expanded whenever additional pertinent data appear. The written material worked over thus far has been drawn from sources close at hand, and there is a likelihood that information in European and even American libraries will yield further large returns.

Another objective of the research program has been the preparation of a general bibliography or Master Index to materials for the study of St. Augustine. Eventually this will lead, it is hoped, to the publication of a guide to the historical sources on St. Augustine, which will give the location, the characteristics, and an evaluation of this material. With this overview of the materials for research, it will then be possible step by step to work through them, collecting, copying, and concentrating, until the final stage of research is reached in the development of special monographs upon particular phases of this community's history, and, as a climax to the whole program, a general publication of sources and a definitive history of St. Augustine. While by no means complete, the Master Index has grown in the first year to be a voluminous record.

With this general view of the St. Augustine Historical Program, and especially of the approach to the research work, a brief description of particular research projects may be of interest.

As the work got under way, and the sifting of local materials began, it became apparent that the more than a half-century program of the St. Augustine Historical Society had resulted in the accumulation of many important source materials, despite a disastrous fire in 1914, which swept the earlier quarters of the Society away and caused the loss of many of the collections. In its present home in the "Oldest House" and Webb Memorial Building, undismayed by the tragedy, the Society has continued to carry forward a strong program and has again built up a good library and a fine collection of old maps and pictures, as well as old letters, diaries, relics, and museum objects generally. The research staff of the Historical Program is now cooperating in making the first comprehensive catalogue of the Society's materials.

Another early "discovery" was the Catholic parish records in fourteen manuscript volumes, covering the period from 1594 to 1763; these were returned a few years ago from Havana, Cuba, to St. Augustine. They undoubtedly are the oldest church records of their kind in the United States. They were found to be in very bad condition, so bad indeed that some of the volumes could not be handled safely, let alone read and used. With the help of both Dr. Merriam and Dr. Leland of the National Committee, who called the attention of the National Archives to these records, the Archives Establishment arranged for their processing, page by page, using the new cellulose acetate method. This work has been finished and the thousands of pages of extremely valuable historical data are now available for use. Two complete photostatic copies of all fourteen volumes have been made, financed by the St. Augustine Historical Society, one copy going to the Society's library, and the other to the National Archives. The original records have been returned to the Parish House. Because of the form in which these records were kept, they constitute an almost complete catalogue of family names for the first Spanish period, omitting the first thirty years. The data on births, parentage, marriages, deaths, and even the geographical record of family migrations make these volumes unique, when one considers the fact that they were written in Spanish and Latin in the sixteenth and seventeenth centuries, as a record of the oldest community of Europeans on the Atlantic coast. A name index is now planned to cover all fourteen volumes, in the preparation of which the research staff will cooperate with church authorities.

Other government and church archives, of apparently unlimited quantity, have been located, the Archival Guide series of the Carnegie Institution proving of great help in this connection. All references to Florida and St. Augustine in this Guide series have been extracted and included in the Master Index, and the American and European libraries where the material is located definitely ascertained. Chief among the source collections of this category in the United States relating to St. Augustine are, possibly, the East Florida papers in the Library of Congress, for which a detailed bibliography has been made, also now covered in the Master Index. In the same library are other important source materials, such as the Lowery collections, many early land records, and quantities of photostatic materials copied from records in European archives, obtained in part by

the Florida State Historical Society, Mrs. Jeannette Thurber Connor, Dr. James A. Robertson, and others.

Mention should be made too of extensive newspaper collections of early St. Augustine and Florida papers in the Library of Congress. The General Land Office has other records, as does the State Library and state government offices in Tallahassee, not to mention the splendid collection of Floridiana in the Julian Yonge library at Pensacola, and the Buckingham Smith collection in New York. Through the research staff and that of the Federal Writers' Project, some of these materials have already been scanned, while the National Park Service has made available microfilm copy of approximately 1000 entries of the East Florida papers, particularly pertaining to the defenses of St. Augustine, which are now being translated by the research staff and studied in relation to the archaeological work on the moat and third defense line. Dr. Carita Doggett Corse, a director of the federal project in Jacksonville, and also a member of the National Committee, has given assistance in the development of the bibliography and has made possible many entries in the Master Index from Washington and other records. Through another federal project, the local records survey, there has been unearthed a good deal of material from city and county archives, as well as from private sources, for which there have been made available bibliographical entries now being transferred to the Master Index.

Another aspect of the program throughout the past year has been the collection of early St. Augustine pictures and maps; many originals have been copied and enlarged, where the original itself has not been available for the files. Of the pictorial records, it should be pointed out that there are now between 400 and 500 pictures of different historical periods in the files; and the map series, now numbering approximately 125 different historical maps, is by no means complete, inasmuch as a great number of manuscript maps and sketches still remain to be copied and added to the collection. Mention should be made also of approximately 150 architectural photographs of St. Augustine, taken by Miss Frances B. Johnston, as a part of her activity in photographing the ancient homes and other structures in Maryland, Virginia, the Carolinas, Georgia, and Florida. The pictorial record, especially where it is possible to get illustrations of different periods for a given site, is graphic historical material of the best kind.

During the year special studies have been undertaken, dealing with the compilation of data upon the folk history of St. Augustine. In this connection a general committee for the study of Minorcan history has been formed, and through Mrs. Kate Lawson and Miss Emily Wilson, of the St. Augustine Historical Society, much material has been collected upon the early inhabitants in anticipation of a possible research project of the American Council of Learned Societies in the field of linguistic and folk studies at St. Augustine. Moreover, with the assistance of Dr. William E. Lingelbach, of the National Committee, Mr. Robert S. Caldwell, of the University of Pennsylvania, and the research staff, an outline has been drawn up, looking toward the inauguration of a study of the period when St. Augustine



was the great resort area of Florida. This project, which may be sponsored eventually by an important national organization, involves an economic-sociological analysis of the Flagler era in the late nineteenth century.

Special studies in medical history have been progressing for some time under the cooperation of the St. John's Medical Society and the research staff, as also has a series of legal studies undertaken by the local Bar Association, looking toward zoning and better community organization. Another special study has been one dealing with early military defenses and early roads of St. Augustine and vicinity.

Archæological and architectural studies have gone hand in hand with the above-mentioned research program. The fifty or sixty outstanding historic sites at St. Augustine have been given careful study, and several vacant lots, as well as the third defense line, have been thoroughly explored, using archæological methods with interesting results. Already thousands of historical objects, some of them related to aboriginal history six centuries and more ago, have been discovered and are being carefully studied and classified. Architectural analysis of the elements of what might be called the St. Augustine type of architecture also has been started, though there is need to set up a project which will have as its purpose the consideration of St. Augustine construction against a background of general Spanish and other architectural influences.

In several cases, architectural studies have been undertaken in order to guide the repair or general reconstruction of historic houses, as in the work with the Sanchez House, an eighteenth-century building, and the Catholic rectory, a nineteenth-century building. This guidance has been given too in the case of the development of several new business houses in the "old section," where an attempt is being made to simulate the St. Augustine architectural type in the interest of a general harmony.

The archæologist and the architect have had their part, along with the historian and the engineer who drafted the plans, in preparing the studies suggesting the basis for such "sample" reconstruction of the moat, the coquina bridge, and the third defense line as may be decided upon. These plans have been preceded by exacting research, involving the careful examination of evidence and the formulation of tentative conclusions. The engineer also is concerned with the preparation of a detailed city map, including topography, as a basis for the correct mapping in the future of all historic-sites research, and as the basis of development plans. Two districts, A1 and A2, have already been completed.

As the research in progress continues, many new avenues doubtless will open. Particularly will this be true of certain fields in natural science, such as botany, geology, and palæontology, which may well throw light on the life history of the environment of St. Augustine.

The research staff to date has consisted of one historian, one archæologist, one engineer, and three research assistants, in addition to the Institution's research associate, who has acted as director of the St. Augustine Historical Program. In addition, a part-time engineer-draftsman, and an architect, who has served in an advisory capacity without compensation, are included in the present staff.



## SEISMOLOGY

Willis, Bailey, Stanford University, California. *Studies in comparative seismology: Report of progress in the study of seismic activity and its causes.* (For previous reports see Year Books Nos. 29-32.)

With the publication of the monograph, *African plateaus and rift valleys*, in May 1936, the data available for discussion of earthquakes and their causes from the point of view of comparative studies were reduced to incomplete observations of conditions in Japan and the Philippines, dating from 1926 to 1927. It had become necessary to supplement those studies and desirable to extend them to the active regions of the Dutch East Indies and British India. With this object in view Dr. Willis left San Francisco on September 15, 1936, and he has spent twelve months in pertinent geologic investigations in the countries named.

As a result of the research begun in California about 1920 and extended to Chile <sup>1</sup> in 1923 and subsequently to Palestine, East Africa, and New Zealand, it has become clear that earthquakes are normal incidents of mountain growth, and that seismic regions of today are those in which mountain growth is now active. The young mountain ranges have been developing by uplift of one type or another since middle or early Tertiary time. Thus this inquiry resolves itself into an investigation of the dynamic activity of any seismic region, as manifested during the later geologic periods in the uplift of mountain ranges. It is also concerned with the related processes of volcanism where volcanoes occur.

Dr. Willis' itinerary, 1936-1937, has covered Java, northern Sumatra, Peninsular India, the Philippines, Formosa, central Japan, and Hokkaido. A prime object of the journey has been to establish in each country an understanding with the working geologists, whether on official surveys, in universities, or otherwise engaged, with a view to frank discussion and the exchange of publications. This purpose has been cordially welcomed, and the results are most gratifying. Full acknowledgments will eventually be made in proposed publications, but mention is here due to Dr. A. W. Heron, Director, Geological Survey of India; Dr. J. Zwierzicky, Chief Geologist of Geological Survey, Netherlands East Indies; Dr. Angel Argueles, Director, Bureau of Science, Manila; Professor Takeo Kato, Dean of Geology, Imperial University, Tokyo; and Professor N. Yabe, Tohoku Imperial University, Sendai, Japan.

For the work in the Philippines Director Argueles, supported by Director Q. Abadilla of the Bureau of Mines, proposed a cooperative arrangement for extensive field work, and it was agreed that the Commonwealth should pay expenses, while Dr. Willis would give his services. The plan, having been approved by President Quezon, was put into effect in the spring of 1937. The observational work occupied three months. Every large island of the Archipelago was visited and geologically examined, so far as practicable. Dr. Willis then wrote a preliminary report,<sup>2</sup> which embodied the tentative results

<sup>1</sup> Earthquake conditions in Chile, Carnegie Inst. Wash. Pub. No. 382, 1929.

<sup>2</sup> To be published by the Bureau of Science, Manila.

of observations bearing on the origin and structure of the islands, together with recommendations regarding the work of the Geological Survey which the government proposes to organize. It appears that the framework of the Archipelago consists of intrusive igneous rocks of late Mesozoic or early Tertiary age, and that important mineral deposits of gold, chromite, etc. are associated chiefly with them. It was therefore recommended that the mapping of the intrusives and of the associated ores be made the first objective of the proposed Survey. In these proposals Dr. Willis and Dr. H. F. Bain, Consultant on Economic Geology to the Commonwealth, were in agreement. In connection with the reconnoissance of the Philippines acknowledgments are due Major General L. R. Holbrook, Commanding General of American Forces in the Orient, who greatly facilitated operations by providing opportunity for Dr. Willis to fly more than four thousand miles to reach remote or otherwise inaccessible points.

Among the broader results of the studies in comparative seismology is the development of a hypothesis of terrestrial dynamics, which rests upon the assumption of intermittent heating in local foci by radioactive agents and finds therein causes for uplift, subsidence, and lateral displacement of segments of the earth's crust, in accordance with physical and mechanical principles. The general ideas have been stated in a previous report (Year Book No. 31) and the hypothesis was tested as an explanation of conditions in East Africa in the volume *African plateaus and rift valleys*. The observations of the past year make it possible to confront the theory with a large body of pertinent facts. The assembling of the facts as personally observed or as stated in the literature on the various countries visited and the formulation of further deductions from them constitute the task to which Dr. Willis now turns. It is hoped the results may eventually appear in a monograph to be titled "Geologic problems of the Orient."

## OFFICE OF PUBLICATIONS<sup>1</sup>

FRANK F. BUNKER, EDITOR

In the preceding reports of the Office of Publications, to be found in the Institution's Year Books Nos. 33, 34, and 35, the publishing activities of the Institution, viewed as an organic whole, have been sketched and some of the problems discussed. In the present report it seems desirable to describe and characterize the contributions made to the publishing practice and program by the principal administrative units of the Institution's organization.

As now constituted the Institution's regular staff of investigators is grouped into Departments and Divisions, each major unit being engaged in coordinated study of related problems. In addition, a number of investigators (Research Associates), affiliated with other agencies, are pursuing specific investigations under short-term grants conferred by it. Some of the investigations made by the Research Associates are conducted in close cooperation with the work of Institution departments. Indeed, in some instances, the department head invites specialists in various subjects to join his staff for a time in order that some item of his departmental program may be covered for which he is not suitably staffed. On the other hand, in instances, the studies upon which the Research Associates are engaged are independent of departmental programs and of departmental supervision.

Reports on the progress of the investigations thus conducted are constantly being published, some in monographic form for permanent record, some in scientific journals and in the proceedings of scientific societies for the current use of specialists, some in form suited to the audiences served by the newspapers and the popular magazines, but all finding place, in summary or bibliography, in the Year Books of the Institution.

A brief description of the organization and work of three of the major Departments and Divisions of the Institution follows, and a sketch of the contributions which each has made to the publishing program of the Institution. The space limitations of this report make it necessary to postpone similar treatment of the remaining units of the Institution organization until the next succeeding Year Book is published.

### THE DIVISION OF ANIMAL BIOLOGY

Until January 1, 1935, the following Institution groups now forming the Division of Animal Biology functioned as independent units: the Department of Embryology at Baltimore; the Department of Genetics at Cold Spring Harbor, Long Island, with its Station for Experimental Evolution and its Eugenics Record Office; the Nutrition Laboratory at Boston; and the Tortugas Laboratory on Loggerhead Key, Tortugas. To simplify administration and to make possible closer and more effective cooperation among the investigators, on the date above mentioned these units were merged, without loss of identity, into the Division of Animal Biology with

<sup>1</sup> Address: Carnegie Institution of Washington, Washington, District of Columbia.

administrative responsibility settled upon the head of the Department of Embryology.

#### THE DEPARTMENT OF EMBRYOLOGY

A grant was made in 1913 to Professor Franklin P. Mall to enable him to prepare a plan of research on the development of the human embryo. A year later the establishment of the Department, with Professor Mall as Director, was authorized by the Board of Trustees. Gradually a permanent staff of investigators, laboratory assistants, trained technicians, modelers, and an artist was assembled. On the death of Professor Mall in 1917, Dr. George L. Streeter, the present Director, was appointed.

The major researches of the Department, which are carried on in the new Hunterian Laboratory of the Johns Hopkins Medical School, Baltimore, are concerned with human embryology and center about a collection of specimens which is constantly growing through the cooperation of the medical profession. Much time has been devoted to study of the external form of embryos which are under thirty millimeters in length, with a view to dividing the period of development represented into stages and establishing a norm for each stage. Supplementing this study, measurements have been made of the older fetuses and these measurements correlated with body weight at different weeks of fetal life. This makes possible the determination of the age of an embryo with greater precision; it also throws light on anatomical variations and racial differences in anatomy heretofore almost wholly unknown.

As a routine activity of the Department, the anatomy of the various organs of the human embryo in successive stages of their development is being studied and already the principal structures of several specimens from the presomite period up to a period representing four millimeters of length have been modeled and described.

Much attention is being given to the pathological aspects of embryology and their bearing upon fertilization, malformations, sterility, and the relation of germinal constitution to subsequent longevity. So, also, since the structure and physiology of the cell is basic to embryology, the subject of normal and abnormal cell-growth is being studied continuously with notable progress made in obtaining information about the factors involved in the origin and growth of tumors.

Through the medium of a colony of macaque monkeys, experimental investigations have been extended into a primate form which closely approximates man in essential respects. Study of these animals concerns, first of all, the physiology of reproduction and the implantation of the egg, with extension of study to the functional and structural development of the embryo and the more fundamental aspects of the physiology of the developing nervous system.

Many papers arising from the activities of this Department have been published in medical, anatomical, biological, and physiological journals. The longer papers and those calling for special illustration are published by the Institution in a series bearing the title "Contributions to Embryology." Since 1915, when the series was started, 26 quarto volumes, containing 159



separate papers, profusely illustrated with color and half-tone plates, have been issued.

#### THE DEPARTMENT OF GENETICS

Study of experimental evolution was formally begun by the Institution in 1904 with erection of a laboratory for the purpose at Cold Spring Harbor, Long Island. The work was directed by Dr. Charles B. Davenport. In 1910 Mrs. E. H. Harriman purchased a farm near the Laboratory and established the Eugenics Record Office. In 1921 the two activities were combined into a Department of Genetics with Dr. Davenport serving as Director until his retirement in 1934, when administrative responsibility was vested in Dr. Albert F. Blakeslee, who in 1936 was made Director.

The work in genetics, which is carried on at the Station for Experimental Evolution, comprises investigation of the laws of inheritance in certain plants and animals which have been found to be especially suitable for such study. The Eugenics Record Office considers the application of these laws to man and studies the biological factors involved in race betterment and deterioration. Both sections of the Department are closely interrelated, and also related cooperatively with other departments of Carnegie Institution in researches of common interest.

In experimental evolution the investigations have covered such matters as: the germ plasm, its architecture, its mutation, and the interactions of the chromosomes; the genetics of *Datura* (Jimson weed) and the flies *Drosophila* and *Sciara*; and the physiology of reproduction, growth, and development with special reference to sex, its essential nature and its experimental control, and to the endocrine glands as controllers of development.

The work of the Eugenics Record Office is conducted under the leadership of Dr. H. H. Laughlin. Included in its program of activities are the following items: to serve as a repository and clearing house for eugenical information; to build up an analytical index of the basic qualities, physical and mental, of human races and family stocks, particularly of American families; to train field workers in gathering data of eugenical importance; to maintain a scientific staff for gathering, analyzing, and interpreting eugenical data; to develop standards of measurement of human traits, physical and mental, including qualities of character or personality; to aid in the discovery of the laws governing the transmission of definite physical and mental qualities from one generation to the next; and to investigate the nature of those forces or agencies which improve or impair racial or family-stock qualities.

Progress in study of genetical problems has been so rapid that investigators have felt the need of prompt publication; in consequence, technical journals have been relied upon largely in making available reports upon the results obtained by the Genetics staff. It has been estimated that the number of papers issued through these channels since the Department was organized will approximate 1400. In addition, the Institution has published 58 monographs, all dealing with the investigations of the Department staff and of the Research Associates who have been and are now working in the field of genetics.

The recent publications of Dr. Laughlin, of the Eugenics Record Office, and his staff have related chiefly to immigration, to sterilization, and to the population conditions of Pan America. In study of the last subject a codification and analysis of the immigration-control laws of each of the several countries of Pan America has been completed and versions in both English and Spanish have been mimeographed. Meanwhile, Dr. Laughlin is prosecuting his notable study of the inheritance of racing capacity in the thoroughbred horse as revealed through analysis of the performance records of approximately ten thousand of the best thoroughbreds in England, France, and the United States. This study, supported by a prominent breeder and successful racer of thoroughbred horses, has been in progress for more than ten years. It is expected that it will be ready for publication by 1938.

#### THE NUTRITION LABORATORY

During the first few years the researches on human nutrition conducted by the Institution were supported by short-term grants and the work was carried on in the chemical laboratory of Wesleyan University, Middletown, Connecticut. In 1907, however, the Trustees authorized establishment of the Nutrition Laboratory under the directorship of Dr. Francis G. Benedict, and the erection of a building in Boston suitable for the work.

During the three decades which have since elapsed, the Laboratory staff and associates, under the leadership of Dr. Benedict, have centered their efforts upon investigations that gave promise of bringing into clear view fundamental laws governing the vital activities of the body, particularly those which relate to conversion of the chemical energy of food into physical energy, the energy which makes it possible for the body to perform the various kinds of work required of it.

The essential feature of this conversion, which takes place within the body tissues, is the combining of the chemical compounds of the food with oxygen. The process is a combustion in which heat is produced. The key therefore to study of body energy is body heat, and it is to matters linked with production of body heat, as affected by digestion and physical exercise, and its loss, as affected by factors both internal and environmental, that Dr. Benedict and his colleagues have directed their thirty-year attack.

In the effort to discover the laws relating to the production and loss of heat in the human body, the program of research which was adopted is an exceptionally broad one, one that embraces not only study of persons of both sexes and of various ages, races, and conditions, but also the study of similar matters among various types of animals.

In planning the program, attempt has been made to divide the work of the staff about equally between studies upon persons and studies upon animals. Investigations belonging to the first group have covered such subjects as the metabolism and growth of infants and children; the metabolism of the very elderly; a comparison of the metabolism of representatives of various races; the consumption of energy in physical and mental effort. In addition, special mention should be made of the very detailed study of a subject who, under close observation, subsisted for thirty-one days without food, drinking the

while only a pint and a half of distilled water per day; and of the study of the effects on the vitality and efficiency of twelve young men who for four months were kept on a dietary which supplied them with only from one-half to two-thirds of their caloric requirements.

The studies upon animals, made because of the bearing these would have upon problems of human nutrition, cover the metabolism of cold-blooded animals, of wild birds, and of warm-blooded animals.

Information was needed about heat production and heat loss when body cells are at low temperature, so an extensive series of heat measurements of cold-blooded animals was undertaken. During this study experiments were conducted on giant tortoises, lizards, alligators, the smaller snakes of various kinds, boa constrictors, and a female African python when coiled around a clutch of eggs which she was incubating. In course of this investigation more than a thousand observations were made. Particular attention was directed to the rôle of metabolism in periods of repose and during digestion, with special regard to the effect of variations in environmental temperature.

Again, it was deemed important to learn about the behavior of body cells living normally at a temperature which in man would indicate a condition of fever. This was found possible by taking as subjects a large number of wild birds whose body temperature is considerably higher than that of man.

Among those studied, numbering twenty-four in all, was a cassowary, weighing thirty-nine pounds; the great condor of the Andes, with a wing-spread of ten feet; a Javan adjutant, a trumpeter swan, a pelican, a flamingo, four herons, an owl, and a sea gull.

Each of these, one at a time, was placed in a hermetically sealed but well-ventilated chamber, equipped so that the carbon dioxide given off from the lungs, and the oxygen used in respiration, could be carefully measured. With the data thus secured, the heat production of each bird was readily computed.

Study of the metabolism of warm-blooded animals has embraced representatives of many species and individuals of many sizes, ranging from a seven-gram dwarf mouse to a sixteen hundred-pound Percheron horse. Very recently this size-range has been pushed upward to include a four-ton elephant, the largest mammal that is available. In commenting upon this range in size, with the mouse at one extreme and the elephant at the other, Dr. Benedict has this to say:

"Owing to the fact that it is the smallest mammal, extensive studies on the mouse have been deemed important. This animal is possessed of a peculiar metabolism in that its temperature has a tendency to vary with that of the surrounding medium. The measurements of the mouse, therefore, partially tie in the warm-blooded series of animals with the cold-blooded series.

"The elephant, because it is the largest terrestrial warm-blooded animal, is just as necessary to the picture as the mouse. The elephant is several times as large as the next largest available mammal, that is, the fattened steer or the Percheron or Clydesdale horse. To attempt to predict the probable metabolism of an animal of 5000 kg. from measurements on an animal weighing only about 750 kg. is questionable, as are all extrapolations. From the standpoint of size alone, therefore, the study of mammals, to be complete, should include an investigation of the physiology of the elephant, particularly of its food and metabolism."



The results of the studies conducted by the staff of the Nutrition Laboratory and associates have by design been published very widely in foreign journals. Thirty-two papers, for example, have had original publication in German journals, 11 have appeared first in French journals, and a dozen or more in journals of other foreign countries.

Information about the progress of these investigations has also been disseminated abroad very widely through lecture tours in European countries made at various intervals by Dr. Benedict and members of his staff. More than 130 lectures on the work of the Laboratory have been given overseas since 1920, when this method of making the results available was initiated.

The response which these lectures have received has been commented upon by Dr. Benedict, who has said:

"The fact that the Nutrition Laboratory will present new, unpublished material, illustrated with lantern slides that have more often than not never been seen by an American scientific audience, and through the generosity of the Carnegie Institution of Washington be able to present it without honorarium or any expense on the part of the European institution, has been deeply appreciated by every organization."

Many lectures have been given by the staff in this country, likewise; so, too, many papers growing out of the work of the Laboratory have been published in American periodicals. Preparation of papers and lectures, however, has by no means monopolized the expository activities of Dr. Benedict and his staff. The Institution's *Catalogue of publications*, for example, contains the titles of 35 books written by members of the Laboratory staff and Research Associates, working in collaboration, which have been published by the Institution in its Monographic Series.

#### THE TORTUGAS LABORATORY

The Laboratory was built on Loggerhead Key, Tortugas (Gulf of Mexico), in 1904, the site being occupied under a revocable license from the United States Department of Commerce, which maintains a lighthouse station on the key. The work was inaugurated by Dr. Alfred G. Mayor and conducted under his directorship until his death in 1922. Since that time the Laboratory has been open each summer, with Dr. W. H. Longley serving as Executive Officer until his death in March 1937.

The site was chosen on account of the purity of the water surrounding the Tortugas group of islands, the proximity of the Gulf Stream with its abundant life, the presence of rich coral formations, and the absence of local fisheries disturbing to marine life. The Laboratory is equipped to afford excellent facilities for a limited number of investigators.

Since the temperature of the water in the laboratory tanks is practically the same as that of the ocean, unusual opportunity is afforded for the maintenance of life in an environment closely approaching that of nature, thus permitting many experiments in physiology which could be carried out only with difficulty, if at all, in the laboratories of temperate regions. Experimental studies in ecology, heredity, regeneration, and growth, the intensive study of the geology, botany, zoology, and physiography of coral reefs, and problems of the chemistry and physics of the tropical ocean in its relation



to life have engaged the attention of the many investigators who have worked at the station.

Systematic zoology and botany have, however, not been neglected, and monographs upon Pacific corals and annelids, ctenophores, echinoderms, Foraminifera, plants of the Tortugas, and Medusæ of the world have been published by the Institution.

From 1917 until 1920, four expeditions were despatched to study the reefs of Tutuila, American Samoa, and investigators have prepared papers upon the volcanic rocks, geologic history of the reefs, the marine land plants, the corals, Alcyonaria, and fishes, growth of marine animals, physiology, ecology, and structure of the reefs, the growth rate of corals and the factors tending to disintegrate the reefs, the bottom deposits, the Foraminifera and diatoms, borings through the reefs, and the meteorology of the region. This is the first thorough study of any high island of the Pacific in relation to its coral reefs which has yet been undertaken by any agency.

Although many papers growing out of the work of the Laboratory have appeared in technical journals, both foreign and domestic, the Institution itself has published nearly 200, in 31 quarto and octavo volumes, illustrated with reproductions of many drawings and photographs. In addition to these volumes of "Papers from the Tortugas Laboratory of the Carnegie Institution of Washington," which deal with investigations conducted in whole or in principal part at the Tortugas Laboratory, the Institution has published 23 volumes in its regular Monographic Series.

#### THE DIVISION OF HISTORICAL RESEARCH

In February 1903 the Institution set up a Bureau of Historical Research under the directorship of Dr. Andrew C. McLaughlin. In 1905 Dr. McLaughlin resigned and was succeeded by Dr. J. Franklin Jameson, who remained Director until his retirement in 1928. During the period of Dr. Jameson's directorship the unit was known as the Department of Historical Research.

Upon retirement of Dr. Jameson the staff was grouped administratively with a unit working in the field of aboriginal American history, and another unit working independently on the history of science. Thus, in 1929, the Division of Historical Research, under chairmanship of Dr. A. V. Kidder, was created, comprising the Section of United States History (formerly the Department of Historical Research), the Section of Aboriginal American History, and the Section of the History of Science. Through further reorganization, effective January 1, 1937, the Division now comprises the Section of Aboriginal American History, the Section of Post-Columbian American History, and the Section of the History of Science.

A brief characterization of the work of these sections and of the publications emanating from each follows:

#### THE SECTION OF ABORIGINAL AMERICAN HISTORY

From its beginning the Institution, by grants or through the efforts of its regular staff, has fostered the study of peoples who have left few or no

written records. Notable among such studies were those by Raphael Pumpelly in Turkestan, in 1903 and 1904, reported in three quarto volumes, and the study of Roman building construction as represented in the aqueducts of Rome, a study made by Dr. Esther B. Van Deman, whose monograph was issued by the Institution in 1934.

The major effort in archæology, however, has centered upon the Maya area of Middle America and the Pueblo region of the southwestern United States. Work in the first of these fields began in 1914 with the appointment of Dr. Sylvanus G. Morley as Research Associate. After ten years of exploratory work in Central America, during which period many ruined cities of importance were discovered, systematic excavation was undertaken, first at Chichen Itza, in Yucatan, once the largest of the Maya New Empire cities, then, later, at Uaxactun, Guatemala, the site of the oldest known Maya ruin. Quite recently the excavational program has been extended to include ruins in the highland region near Guatemala City and also at Copan in Honduras. As a result numerous remarkable examples of Maya architecture have been cleared, repaired, and put in condition for inspection and study, condition which, it is expected, will insure their preservation for many decades to come.

In course of this work numerous questions have arisen which cannot be answered by archæological methods alone. In consequence, under leadership of Dr. Kidder, a broad program of Maya research has been inaugurated. This program has included many special investigations such as: the geology of the Maya area; Maya astronomy; the engineering knowledge of the Maya; Maya chronology; the phytogeography of Yucatan; the folk literature of a Yucatan town; the food of the present-day Maya; the botanical history of maize; the animal life of the cenotes; the mode of life in a Maya village of the present day; and, finally, to cite but one other example, a three-year study of the medical, biological, meteorological, and sociological features of the Yucatan Peninsula, a study in which many specialists cooperated.

Intermittently during the past twenty years field work in the Pueblo region of southwestern United States has been conducted by Carnegie Institution and other agencies. Earl H. Morris, of the Section staff, who has done much work in the region for the Institution, spent the latter half of 1936 in preparing a report on the results obtained in the La Plata country by the various agencies. The period covered represents about seven hundred years in the cultural progression of the inhabitants, a period extending from Basket Maker III to the close of Pueblo III, or about A.D. 1300. Since completion of the report Morris has been studying the rich collection of material obtained from cave sites in the Red Rock district of northeastern Arizona, materials obtained through excavations by Carnegie Institution in 1931. The period represented has been defined as dating from about A.D. 477 to A.D. 700. Eventual publication of these and of other studies which the Section is conducting will provide a comprehensive picture of a relatively early and important stage in the cultural history of the Southwest.

Sixteen detailed and voluminous reports on the work of this Section have already been published by the Institution and issued in its Monographic Series. A number of these reports are profusely illustrated, some with many

plates in full color. In addition, many short papers have been prepared by the staff. These have been gathered into quarto volumes and issued as "Contributions to American Archæology from Carnegie Institution of Washington." Of this series, begun in 1931, 4 volumes containing an aggregate of 24 papers have so far been published.

#### THE SECTION OF POST-COLUMBIAN AMERICAN HISTORY

Until 1929, when the Department became a section of the new Division, the staff under leadership of Dr. Jameson, the Director, was occupied principally in locating and examining collections of source material dealing with the early history of North America and issuing guides to such material as aids to investigators in American history. In prosecution of this program members of the staff not only canvassed all known sources in the United States, but extended their investigations to the archives of all countries having contact with North America during the periods of discovery, exploration, and colonization.

As fruit of this study the Institution has published numerous guides to documents relating to American history, documents which are to be found at Washington, in Protestant church repositories, in Canadian archives, in the British Museum, in London archives, in the libraries of Oxford and Cambridge, in the Public Record Office of Great Britain, and in the archives, respectively, of Spain, Mexico, Cuba, Italy, Germany, Switzerland, Austria, Russia, the British West Indies, and Paris. Reports were also made on the materials bearing upon American history to be found in the Netherlands and the countries of Scandinavia.

In addition to these guides to sources, the staff, under supervision of Dr. Jameson, began the preparation of material for several series of volumes, including: *European treaties bearing on the history of the United States and its dependencies*, 4 octavo volumes; *Letters of members of the Continental Congress*, 8 octavo volumes; *Historical documents relating to New Mexico, Nueva Vizcaya, and approaches thereto, to 1773*, 3 octavo volumes; *Proceedings and debates of the British Parliaments respecting North America*, 4 octavo volumes; *Correspondence of Andrew Jackson*, 7 octavo volumes; *Judicial cases concerning American slavery and the Negro*, 5 octavo volumes; *Documents illustrative of the history of the slave trade to America*, 4 octavo volumes; and, finally, the *Atlas of the historical geography of the United States*, a single volume comprising 166 colored maps and 161 pages of descriptive text.

From time to time during the past thirty-two years the Institution has issued volumes in development of these series. Except for publication of further volumes in the series, *Guides to materials for American history in the libraries and archives of Paris*, now nearly ready, and in the series, *Proceedings and debates of the British Parliaments respecting North America*, Dr. Jameson's monumental program of historical research has been completed.

Meanwhile, since reorganization in 1929, the Section staff, a staff now comprising a younger personnel for the most part, has entered upon study of historical material which deals more closely with problems raised by the



Institution's archæologists who are seeking a fuller understanding of the Maya of Middle America, who attained high cultural place during the pre-Columbian period.

As has already been mentioned, in study of the Maya many questions have arisen which cannot be answered by archæological methods alone. In order to meet the need a broad attack has been organized, one which brings into action investigators representing the numerous applicable disciplines. Occupying important place in this program are members of the Section of Post-Columbian American History. Some of them are engaged in study of the large and territorially widespread group of tongues belonging to the Maya linguistic stock. Others are attempting to bridge the gap between the present and the prehistoric past of the Maya through study of the documents relating to the Spanish conquest of the Maya peoples and to the subsequent relations which developed between the conquerors and the conquered, relations in which both groups were profoundly and reciprocally influenced.

An account of the investigations now in progress which are being conducted by members of the reorganized Section, and of the publications that are expected to result therefrom, will be found in the report of the Division Chairman which appears in the present Year Book.

#### THE SECTION OF THE HISTORY OF SCIENCE

The great importance of the work upon the history of science by Dr. George Sarton, and the desirability of bringing it into close relation to other studies upon the intellectual evolution of mankind, led to formation of this Section and its incorporation in the Division of Historical Research.

As a distinct discipline, the history and philosophy of science may properly be said to have been founded by Dr. Sarton, for, until he began working in this field, no attempt had been made to write a systematic and comprehensive survey of the knowledge of science and learning which the world possessed at successive periods beginning with the earliest times.

To make a start at tilling such an enormous field, it was necessary, Dr. Sarton thought: first, to establish a periodical which would serve as a repository of current studies, as a forum for the critical discussion of sources, and as a convenient place for the listing of bibliography; second, to begin preparation of a preliminary outline of intellectual achievements in all lands and throughout all ages.

The initial step was taken in 1912, while Dr. Sarton was still resident in Belgium, through the founding of *Isis*, a journal devoted to the history of science and civilization, published quarterly. Planning of the outline had already commenced but was suspended during the war. Coming to America during the war, as Lecturer at Harvard University and Research Associate of Carnegie Institution, Dr. Sarton resumed his activities and prosecuted them to such good purpose that as a result *Isis* is now in its twenty-seventh volume, while the first two volumes of the *Introduction to the history of science*, written by Dr. Sarton, have been completed and published by the Institution.

These volumes are the first of the monumental series planned to give a



chronological survey in the form of cross-sections of the world's intellectual achievements for each half-century. The two volumes bring the survey from the dawn of Greek and Hebrew knowledge in the ninth and eighth centuries B.C. down to the close of the thirteenth century of the Christian era. Work on the third volume of the survey, which deals with the science and learning of the fourteenth century, is well advanced. The Jewish part is completed and it is expected that the Latin and European parts will be finished by the end of 1937.

In addition, the Institution has published studies by members of the Section on: *Anatomical texts of the earlier Middle Ages*, an octavo of 112 pages; *Leonardo da Vinci the anatomist*, an octavo of 265 pages, with reproductions of many of Leonardo's drawings; and *The heroic age of science among the ancient Greeks*, an octavo of 203 pages. Mention should also be made of the notable work in palæography done by Dr. E. A. Lowe, long a Research Associate of the Institution and now Professor of Humanistic Studies in the Institute for Advanced Study at Princeton, New Jersey. Certain of Dr. Lowe's studies have been given sumptuous publication by the Oxford University Press, the last of these being brought out by and with the cooperation of the American Council of Learned Societies and the Carnegie Institution.

#### THE DIVISION OF PLANT BIOLOGY

The interest of the Institution in the plant sciences first found expression in the establishment of the Desert Laboratory at Tucson, Arizona, in 1903. In 1905 the Desert Laboratory became the headquarters of a Department of Botanical Research with Dr. D. T. MacDougal as Director. In 1909, under the auspices of the Department, a Coastal Laboratory was established at Carmel, California, where investigations correlative to some at the Desert Laboratory were conducted, investigations several of which developed into major projects of the Department. In 1923 the name was changed from Department of Botanical Research to Laboratory for Plant Physiology and so remained until 1928, when it was joined with other groups to form the Division of Plant Biology, under the chairmanship of Dr. H. A. Spoehr.

The division today consists of a number of relatively small groups of workers each engaged upon fundamental problems. Although the major laboratory experimentation is conducted at the Central Laboratory located at Stanford University, the needs of particular groups require that their work be done at other localities and by modes of approach and techniques that are peculiar to the several projects.

An outline of the investigations upon which the various groups are engaged will illustrate both the breadth of the program and the diversity of the projects.

1. The process of photosynthesis, by means of which green plants utilize solar energy, has been under investigation by Dr. Spoehr and a group of associates for many years. The work is now conducted at the Central Laboratory. This marvelous phenomenon, upon which all life depends, directly or indirectly, has been studied with a view primarily to gaining

an insight into the chemical reactions which are involved. In this connection investigations are being conducted on the chemistry of the cell constituents which play a rôle in photosynthesis. These include the substances which constitute the complex photosynthetic apparatus as well as the products which are elaborated by the plant.

2. The investigations in experimental taxonomy, inaugurated by the late Dr. H. M. Hall, are being continued at the Central Laboratory, near sea level, and at two field stations in the Sierra Nevada, at 4500 feet and 10,000 feet elevation. A few groups of characteristic western American plants have been selected for intensive study in the attempt to learn the history of plant life and how the differentiation into the present complexities of relationships took place. The hypotheses formed on the basis of data obtained are being tested, wherever possible, by attempts to repeat Nature's evolutionary experiments.

3. From its establishment in 1903, the Desert Laboratory has been and is devoted to the investigation of the plant life of the region in which it is situated. The aim of the work is to gain an understanding of the history of the plant life of the desert and of the structural and functional adjustments which have made its origin and persistence possible. Measurements of growth, study of germination and establishment of new individuals, recording seasonal behavior in relation to climatic fluctuations, and conducting observations on the precise character of changes in vegetation, are present-day lines of work of which some have been under way for thirty years or more.

4. Since 1913 Dr. Frederic E. Clements and his associates have been working in the field of plant ecology. Studies of adaptation in species have been carried on by means of a series of transplant gardens located at intervals of 2000 feet, extending from the base of Pikes Peak, Colorado, at 6000 feet, to the summit at 14,000 feet, supplemented by gardens at Santa Barbara, California. A major result has been the demonstration that adaptation is probably a universal process, as indicated by the responses of each of the several direct factors on the part of the two hundred or more species employed. The conclusion has also been reached that the effective migration of plants and animals has been primarily under climatic compulsion and that the major movements of the past have caused the active evolution of new forms.

5. The palæobotanical investigations of Dr. R. W. Chaney have been directed toward an interpretation of the significant series of changes which have occurred in the vegetation of western America during later geological time. These changes, apparently associated with changes of climate, are recorded by the fossils of plants which have been collected over an extensive area bordering the Pacific basin, from Alaska to the Isthmus of Panama, and with correlative studies in Asia.

6. The study of historical climatology as revealed by tree-ring records, begun by Dr. A. E. Douglass in 1901, is being pushed vigorously by him and his associates at Tucson and at the Central Laboratory. The effect of climate upon tree growth as recorded in the annual growth rings is very complex, and it is upon this problem that study is now being focused.

As the work of the various groups and their methods of investigation have been as diversified as their problems, so also each group has sought to meet its publishing requirements in accordance with its own needs. Almost every section of the Division has its own particular group of readers and scientific colleagues who desire to keep abreast of the progress being made in the field of their special interest. Moreover, within some sections, types of research have been conducted which involve widely different scientific disciplines, so that the results from a single section have been published through varied channels reaching readers representing different scientific interests.

Although the major portion of the published results from the Division have appeared in journals devoted to the biological sciences, the longer papers representing the accumulated results of extended investigations have been published in the Monographic Series of the Institution. These are listed in the Institution's *Catalogue of publications* under the subject heads of "Botany," with 54 titles, comprising 61 volumes; "Ecology," with 23 titles, comprising 25 volumes; and "Palæontology," with 22 titles that represent extended papers contributed by investigators now grouped with the Division of Plant Biology.

The Statistics of Publications and the Bibliography follow.

## STATISTICS OF PUBLICATIONS

The table which follows gives the Institution's yearly production of monographic publications, now totaling 712 volumes, comprising 208,885 pages of printed matter.

*Production of monographic publications*

Year	Number of volumes issued	Number of octavo pages	Number of quarto pages	Total number of pages
1902.....	3	46	.....	46
1903.....	3	1,667	.....	1,667
1904.....	11	2,843	34	2,877
1905.....	21	3,783	1,445	5,228
1906.....	19	3,166	1,288	4,454
1907.....	38	6,284	3,428	9,712
1908.....	28	4,843	2,485	7,328
1909.....	19	3,695	1,212	4,907
1910.....	29	3,274	4,831	8,105
1911.....	30	5,062	1,670	6,732
1912.....	23	3,981	2,044	6,025
1913.....	29	6,605	2,752	9,357
1914.....	23	4,978	1,934	6,912
1915.....	23	4,686	1,466	6,152
1916.....	35	9,478	2,430	11,908
1917.....	21	4,464	2,691	7,155
1918.....	17	3,073	1,120	4,193
1919.....	29	5,834	2,431	8,265
1920.....	23	3,962	3,710	7,672
1921.....	18	4,068	1,398	5,466
1922.....	24	4,566	2,039	6,605
1923.....	20	6,459	604	7,063
1924.....	17	4,665	834	5,499
1925.....	24	3,970	1,277	5,247
1926.....	14	4,552	850	5,402
1927.....	17	4,520	2,089	6,609
1928.....	15	4,495	1,044	5,539
1929.....	12	4,938	452	5,390
1930.....	15	4,096	844	4,940
1931.....	14	4,017	1,343	5,360
1932.....	16	2,155	2,588	4,743
1933.....	22	4,256	1,370	5,626
1934.....	13	3,030	1,206	4,236
1935.....	9	1,742	813	2,555
1936.....	13	3,395	1,745	5,140
1937.....	25	2,795	1,975	4,770
Total...	712	149,443	59,442	208,885

In addition, during the year, the Institution has issued the following: Seven numbers in its Supplementary Publications Series, comprising 8 articles, chiefly Institution lectures, totaling 136 printed pages, illustrated with many cuts; 11 numbers of the News Service Bulletin, totaling 87 printed pages and carrying 71 illustrations; and 8 numbers of the Clip Sheet, con-



taining 29 short articles relating to the work of the Institution, suitable for use of the press.

*Receipts from sales of publications*

Year	Index Medicus	Year Book	Miscellaneous Books
1903.....	\$2,256.91	\$29.25	.....
1904.....	2,370.47	52.85	\$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970.56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292.89
1908.....	3,406.19	99.65	4,371.67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899.05
1911.....	4,440.21	85.50	6,366.55
1912.....	4,652.14	61.65	6,782.34
1913.....	4,992.02	75.95	7,140.69
1914.....	5,079.16	49.65	6,273.59
1915.....	5,010.21	47.60	5,239.98
1916.....	4,382.19	46.60	8,115.37
1917.....	4,616.21	51.55	7,253.59
1918.....	4,324.29	21.10	5,575.61
1919.....	4,267.95	93.30	8,476.33
1920.....	5,451.86	40.50	12,901.43
1921.....	6,277.32	50.55	10,356.64
1922.....	5,774.59	59.25	8,248.00
1923.....	5,777.46	70.10	7,994.20
1924.....	4,533.68	31.00	7,429.53
1925.....	5,636.25	25.00	8,019.49
1926.....	5,728.31	41.40	8,269.31
1927.....	1,650.65	59.67	8,322.10
1928.....	887.85	87.80	9,948.60
1929.....	433.70	41.74	8,450.47
1930.....	363.65	127.85	8,977.44
1931.....	574.30	159.38	7,749.05
1932.....	119.35	80.60	5,086.28
1933.....	50.20	69.89	4,294.83
1934.....	81.60	50.31	4,500.60
1935.....	29.60	73.28	4,118.52
1936.....	16.40	71.10	5,639.99
1937.....	47.60	88.10	4,528.49
Total.....	111,734.70	2,254.73	216,695.55

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